

Interdependence and Performance: A Natural Experiment in Firm Scope^{*}

Gabriel Natividad

Universidad de Piura, gabriel.natividad@udep.pe

Evan Rawley

Columbia Business School, erawley@columbia.edu

This paper shows how interdependencies influence performance in a predictable manner, following a reduction in the scope of a firm's activities. We test the predictions of the theory using detailed micro-data on every Peruvian fishing firm before and after a regulatory ban on mackerel fishing, and find that reducing the scope of firms' activities causes the productivity of firms' legacy anchovy operations to fall sharply, before recovering in the long-run. The results are most pronounced for firms with the strongest interdependencies between activities. Moreover, we find evidence that the persistence of the productivity decline is explicitly tied to a failure to adapt quickly following the ban. Consistent with our conceptual characterization, the evidence suggests that interdependencies between activities simultaneously create benefits as well as costs, but that costs are more persistent when the firm reduces its scope of activities.

1. Introduction

Under certain conditions, firms can coordinate economic activities more efficiently than markets (Williamson 1985), but hierarchical control is also thought to create negative interdependencies hampering performance in multi-activity firms (John and Ofek 1995). The empirical evidence on scope and performance is mixed too. Scholars have shown that firms can exhibit characteristics of efficient central planning authorities—for example in the transaction cost economics literature, (see Macher and Richmond 2008, for a review)—and also found evidence that broad scope firms operate like inefficient bureaucracies (e.g., Schoar 2002). Yet, in spite of the Janus-faced nature of scope, there is little research explaining how such ostensibly oppositional characteristics operate within the same firm simultaneously (Zhou 2011). In this paper we attempt to shed some light on the tradeoffs inherent in firm scope decisions, by studying the performance implications of activity-level interdependence within firms.

Interdependencies exist where the efficiency of one activity depends on another activity, where positive interdependencies are the joint benefits to performing activities together, sometimes called complementarities (Milgrom and Roberts 1990), and negative interdependencies are the joint costs of

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performing activities together, sometimes referred to as coordination costs (Gulati and Singh 1998). Interdependencies can be vertical, within the process flow of production routines, or horizontal, across related input or output activities. For example, the efficiency of a lumber mill's timber operations depends on how well the log cutting operations excise knotty wood from a fallen tree (Casadesus-Masanell, et. al. 2008); and the productivity of Belgian manufacturing firms' internal research and development activities depends on the extent to which they pursue external knowledge acquisition activities (Cassiman and Veugelers 2006). Our focus in this paper is on the costs and benefits of horizontal interdependencies between related activities.

As in Siggelkow (2001), we characterize the firm as a set of routinized activities for producing output, where one of the firm's key strategic efforts is to create positive interdependencies between activities (Porter 1996). However, by making the organization and operation of the firm more complex interdependencies can also constrain the organization, making it rigid and less adaptable (Leonard-Barton 1992, Kaplan and Henderson 2005). Thus, we treat the firm as a bundle of partially rigid interdependent activities, which interact in ways that may add value in the aggregate, but can be costly at the activity-level, particularly when there are shocks to the composition of the activity system. From this perspective we study the implications of interdependence during periods of stability, when activity scope is constant, and turbulence, when there is a reduction in the number of activities performed by the firm.

By making the choice of activities within the firm endogenous, the conceptual approach embraces a theory of interdependence and scope that does not rely on systematic managerial mistakes—an approach that is increasingly gaining favor in the literature on firm scope (e.g., see Markides 1995, Campa and Kedia 2002, and Colak and Whited 2007). Moreover, by taking organizational rigidity seriously in the context of changing activity systems, our framework makes a clear joint hypothesis: while positive interdependencies will generally outweigh negative interdependencies during stable periods, negative interdependencies are more persistent, and therefore more pronounced when activity scope is reduced.

We study interdependence and performance using detailed micro-data on Peruvian fishing firms' anchovy and mackerel production activities. Interdependence is important in our setting, as mackerel fishing has a direct impact on the productivity of anchovy fishing, in large part because the biological relationship between the species. Mackerel eat anchovy and thereby mackerel fishing gives fisherman asymmetric information about the location of anchovy schools. While the precise nature of interdependence is somewhat unique to the setting—asynchronous, biological interdependence certainly seems unusual—the industrial context fits extremely well with the concept of interdependence as articulated in the literature.

Our key methodological insight is that an unanticipated government ban on mackerel fishing exogenously changed the scope of activities performed by the fishing firms, allowing us to identify the

impact of interdependence on activity-level (anchovy fishing) productivity. Specifically, we compare the changes in activity-level productivity in formerly multi-activity firms (i.e., firms that fished for mackerel and anchovy) relative to changes in productivity in single activity firms (i.e., firms that only fished for anchovy historically) at the ship-week level before and after the ban. Since 41% of the firms were suddenly forced to drop their mackerel operations, the tests are difference-in-differences estimates of performance on a change in the scope a firm's activities. The tests are particularly convincing because: (i) the shock to the scope of activities performed by the firm was exogenous and unanticipated, and (ii) the empirical setting allows us to observe physical measures of inputs and outputs weekly at the ship-level for all firms in the industry, which gives us an unusually precise measure of interdependence (i.e., at the activity level) and performance (i.e., productivity in quantities).

We find that an exogenous reduction in the scope of a firm's activities causes anchovy productivity to fall by 16% at the ship-level during the anchovy seasons, where seasons are defined by government regulation, in the fifteen months following the ban, and are most pronounced for firms with the strongest interdependencies between activities. Moreover, we show that rigidity is explicitly tied to a failure to adapt at the time of the ban. Firms continue to deploy their ships in a manner consistent with multi-activity firms after the ban for some months, even though that deployment strategy appears suboptimal in a single activity firm. The evidence is consistent with the idea that firm's grow through efficiently coordinating activities internally—they expand the activity set under their control when it offers them a net benefit—but struggle to adapt when the benefits of interdependence disappear. More broadly, the results suggest that it is interdependence itself that makes firms rigid, which has implications for a range of corporate strategy decisions.

This paper contributes to the strategy literature in three main ways. First, we show that when organizational rigidity is present, a reduction in the scope of a firm's interdependent activities destroys positive interdependencies while leaving negative interdependencies in place, thereby temporarily negatively impacting activity-level performance. This result is particularly important for firms that engage in related diversification—an important, and arguably understudied, segment of the economy (Zahavi and Lavie, 2013)—as well as for non-diversified multi-activity firms with meaningful interdependencies between activities. Second, while the literature on scope and performance is extensive, we believe this is the first paper to offer large-sample quasi-experimental evidence of both positive and negative interdependence in multi-activity firms. Third, we show that organizational rigidity can be directly linked to changes in the scope of a firm's activities. If firms cannot immediately adapt to changes in their activity systems, they face a cost of organizational change, which influences optimal firm scope decisions both before and after a change in firm scope. While organizational scholars have long posited that adaption challenges are a central concern in firm strategy (Levinthal 1997; Nickerson and Silverman

2003), there has been little research on adaptation costs in the context of the scope of a firm's activities (Sorenson 2003).

2. Theory and related literature

Strategy and organizational scholars have been deeply engaged with questions regarding firm scope at least since Coase (1937); and theories of scope and performance date back at least to Alchian and Demsetz (1972), Williamson (1975), and Jensen and Meckling (1976), who analyzed the firm as a legal and administrative system, or a nexus of contracts. Later, Nelson and Winter (1982) and Porter (1996) offered a complementary theory of the firm conceiving of organizations as nexuses of routines or activities. The activity-based theory of firm has been said to “mouth-watering potential” (Gibbons 2005), because it conceives of the firm in a more operational and veridical manner than administration-centric theories. Firms are not just a book of blueprints, but are also defined by rules of thumb, social relationships, and cultural norms, and the activity-centric perspective on the firm offers some insight into how these micro-organizational features of firms influence real economic outcomes.

Unfortunately the many definitions of “routine” or “activity” in the literature have led to some confusion about how to apply these frameworks to questions of scope and performance (Felin and Foss, 2009). For the purposes of this paper we define an “activity” as a routinized production or administrative process that is physically, intellectually, or temporally distinct from other firm activities. The definition seems to capture the spirit of the original concept and fits well with current characterizations of firms, for example, Puranam, Raveendran, and Knudson's (2012) description of firms as “systems of coordinated activity.” Conceptually an activity could be the smallest non-decomposable process with a firm, or a higher-order activity—a process comprised of sub-activities. While our theory applies at either level, for the purposes of this paper we focus conceptually and empirically on higher-order activities and refer to the components of higher-order activities as sub-activities.

Beyond conceptual classification issues, until recently, data limitations represented a significant barrier for analyzing scope decisions at a level of detail sufficient to address fundamental questions about performance effects accurately (Villalonga, 2004). Indeed, Mullianathan and Scharfstein (2001, p.195) note that “while we know something about the forces that determine firm boundaries, we know relatively little about how these boundaries affect actual firm behavior. This is a major limitation in our understanding of the nature of the firm.”

This paper builds on a growing body of strategy research, which addresses this gap in the literature, by studying the relationship between firm scope and performance at a micro-level of organization, and by integrating different theoretical frameworks in a concrete empirical context. For example, Nickerson and Silverman (2003) integrate transaction cost economics (Williamson, 1985) and the organizational change

literature (e.g., Hannan and Freeman, 1984) to develop transaction-level predictions about the efficiency of vertical integration, which they test in the context of the U.S. trucking industry. Analogously, this paper integrates a theory of the firm with a theory of adaptation to form testable hypotheses about firm scope and performance. And, indeed, there is growing evidence that the activity system perspective can deliver unique insights into our understanding of firm scope and performance. For example, Novak and Stern (2009) show that the larger scope of an activity system can positively influence performance in their study of complementarities in automobile manufacturing firms. Interestingly, in a similar setting—automobile manufacturing firms—Pierce (2012) finds evidence of negative interdependence in the vertical interdependencies between leasing and manufacturing divisions. Relatedly, Feldman (2014) finds evidence of performance declines in firms that divest their legacy business units, suggesting that positive interdependencies are often tacit and deeply embedded in the organizational structure of the firm. While all three papers deliver insight into the nature of interdependence, none explores the tradeoffs inherent the nexus of interdependent activities that define a firm, as we do in this paper.

Of course, we are not the first to posit that interdependencies simultaneously exert positive and negative effects on firm performance. Rawley (2010) and Zhou (2011) showed that related diversification creates both synergies and coordination costs. In a related study on the dynamic duality of interdependence, Gartenberg (2014) examines lending performance in the presence of vertical interdependencies between finance and construction divisions of U.S. home builders during the recent housing crisis. She finds that by severely limiting capital available for lending, interdependence actually led to improved lending standards, and performance during the crisis, suggesting that the value of interdependencies can fluctuate substantially over time as the economic environment changes. We build on this prior work by developing a test of both the costs and benefits of interdependence using a natural experiment, and extend prior research by showing how rigidity influences the dynamic performance implications of interdependence in a context where firms are shrinking instead of growing.

Specifically, we propose that endogenous interdependence between activities within firms leads to predictable patterns of costs and benefits of interdependence in dynamic environments. When organizations coordinate activities, interdependencies arise because decisions made concerning one activity influence the efficiency of other activities (Rivkin and Siggelkow 2003). Because the activity scope of the firm is endogenously determined, benefits of interdependence will generally outweigh costs during stable periods. However, if firms are rigid in the sense that they not able to adjust instantaneously in the short-run (Hannan and Freeman 1984)¹, that relationship will threaten to reverse during turbulent

¹ Because firms may not be able to instantaneously adapt due to task-level rigidities, like the cost of retraining personnel, revising strategic or operational plans, or due to causal ambiguity about the returns to formerly interdependent activities, the concept of organizational rigidity applies well to firms with interdependent activities.

times (e.g., when the scope of a firm's activities change), whether the change is endogenous or exogenous, until the firm manages to adapt to the new environment. In particular, firms that eliminate an activity with significant interdependencies will face persistent negative interdependencies until the firm can reorganize appropriately. For example, if the firm does not organize its administrative or production processes, or a subset of the associated sub-activities, as a more focused firm would, following a change in scope, it is likely to suffer from persistent negative interdependencies. This persistence, or rigidity, could be structural, due to institutional or contractual limitations on the speed of adaptation, or it could be behavioral, due to social or cognitive limitations of managers. We summarize this logic as:

Proposition 1: Interdependence simultaneously creates costs and benefits, but costs are more persistent when the firm reduces its scope of activities.

Our prediction obtains from the application of the theory of the firm as a bundle of activities or routines (Nelson and Winter 1982). We use that theoretical lens to model the multi-activity firm as a set of interdependent, but only partially adaptable, production functions. While much of the prior work on scope and performance has focused on interdependencies related to diversification or divestiture events, implicitly equating firm scope with the number and type of business units owned, the activity-centric perspective lends itself more naturally to a micro-organizational perspective on firm organization. Indeed, often in corporate strategy decisions the concept of firm scope extends beyond a calculus of the optimal collection of business units or divisions. For many firms, strategic questions of scope are also about how to organize the firm at a micro-organizational level, including how the operations of the firm should be harmonized. Thus, our theory encompasses both micro-organizational scope decisions and classic diversification decisions as long as there are meaningful operational or administrative interdependencies between business units, divisions, or products. By contrast, our conceptual approach would not apply well to decisions by conglomerates about whether to sell off a business unit that has little interaction with other business units under the corporate umbrella. Similarly, we would not expect large performance effects to be manifest in firms that pared away an activity from a nexus of activities that had little interdependence. In this sense the theory we provide is an activity-based theory of interdependence and scope.

Below, after discussing the institutional context, we develop a simple analytical framework linking a reduction in firm scope to a particular performance pattern that is the signature effect of Proposition 1. While simple, the framework allows us to analytically develop testable implications of the theory that can be taken directly to the data.

3. Empirical context

3.1 *The Peruvian fishing industry*²,

The Peruvian fishing industry is the second largest in world, generating about \$2.5 billion in annual revenue. The industry value chain includes two vertical activities: fish extraction and fish transformation. The focus of this paper is on horizontal interdependence in the extraction segment. Output is classified into two product segments: indirect human consumption, which includes fishmeal and fish oil, and direct human consumption, which includes canned, frozen and cured seafood. This paper focuses on the fishmeal and fish oil segment, which accounts for about 97% of the fish processed in the Peruvian fishing industry. While several fish species can be used in products for indirect human consumption, the most common by far are anchovy and mackerel.

Much of the industry activity (about 85% by weight) revolves around a single species, anchovy (*engraulis ringens*), which is primarily fished for fishmeal. Anchovy are a slow moving fish that routinely achieve a large biomass in the cool waters of the Pacific Ocean off the coast of Peru during two reproductive cycles each year. The anchovy population is maintained in part through strict and vigorously enforced restrictions on fishing seasons that prohibit industrial firms from fishing for anchovy in the months surrounding the reproductive cycles. The natural conditions of the Peruvian sea and the political environment restricting fishing to two anchovy seasons of approximately three months each year support the highest anchovy landings in the world, around seven million tons per year, though anchovy populations still vary over time due to exogenous biological conditions. Historically, mackerel fishing was the second major activity of the Peruvian fishing industry resulting in about 7%, by weight, of the industry's catches.

The vessels used to catch anchovy and mackerel are called purse seiners. Purse seiners catch fish by surrounding shoals with a net that gets closed at the bottom by tightening a rope and sucking the fish in to the boat using a pump. Nets are expensive and can easily tear if dragged across the ocean floor or when pressed against the fish shoal; therefore, purse seiners may chase a group of fish for some distance before the shoal forms and stabilizes. Fishermen note that mackerel is more difficult to catch than anchovy because mackerel tends to “run” more frequently, moving fast and far when agitated. Thus, the minimum ship size and speed requirements for mackerel fishing exceed the minimums for anchovy fishing. (We control for ship-level heterogeneity in our empirical analysis with ship-specific fixed effects.) Different net systems are also required for anchovy and mackerel, which necessitate changeovers in port; however, beyond altering the net system, other physical adjustments to ships when switching between species are

² Our description of the fishing industry draws from a combination of direct work experience in the empirical context (of one of the authors) and interviews with practitioners including fishing managers, fishermen and analysts. For academic descriptions of this setting, see Bakun and Weeks (2008), Arias Schreiber (2011) and Muck and Sanchez (1987).

relatively minor, mostly stemming from the different styles and activities developed by crews to adjust to the different behaviors of these species. All ships' fishermen are paid proportionately to the value of the fish they catch.

While utilizing fishing boats during the anchovy off-season provides a strong (fixed asset utilization-based) motivation for firms to fish for mackerel, and ship-level heterogeneity influences the ability of the firm to catch mackerel, our interest in this paper is to understand how interdependencies influence activity-level productivity over time. The key positive interdependency between anchovy and mackerel fishing arises from a natural biological synergy—fishing for mackerel gives firms better information about the location of anchovy schools because mackerel tends to follow and feed on anchovy (Muck and Sanchez 1987). But just as interdependence between anchovy and mackerel fishing creates positive effects, it also creates negative effects. In order to take advantage of the mackerel available during the anchovy off-season, multi-activity firms must operate their boats year-round, resulting in a less well-maintained fleet during anchovy season. Also, multi-activity firms tend to distribute their ships differently compared to single-activity firms, which represents an important potential source of persistent interdependence. While single-activity firms tend to cluster their ships close to the shore where anchovy is abundant, but where there is also significant competition, multi-activity firms tend to distribute their boats more widely in order to tap into less competitive fishing grounds. The precise magnitude of the partial effect of these two styles was probably difficult, if not impossible, to disentangle before the ban on mackerel, even for sophisticated firms. Yet in retrospect, with the hindsight provided by the shock to firm scope, it appears that information asymmetry was the key to making the distributed model work effectively. Industry respondents report that the distributed model has largely been abandoned in recent years, which further suggests that by removing the interdependencies between mackerel and anchovy, the distributed model became inferior to the approach of clustering ships close to shore.

3.2 The ban

Prior to 2002, there were no meaningful restrictions on the harvesting of mackerel: it could be fished for fishmeal or for human consumption and it could be fished any time during the year. However, given the relative abundance and ease of catching anchovy and the fact that fishing boats must be retrofitted with different net systems to fish for different species, which could take up to a day, most firms focused extensively on fishing for anchovy during the anchovy seasons, and then shifted their activities to mackerel fishing during the anchovy off-season. However, some firms did switch back and forth between anchovy and mackerel during anchovy season. By nature of the food chain, mackerel fishing gave “switchers” access to asymmetric information about more far-flung anchovy shoals in-season, and even firms that never switch between anchovy and mackerel during anchovy season were able to take

advantage of an important one-time information advantage at the beginning of the season. Interestingly, this one-time asymmetry can be substantial and fairly long-lived, as anchovy biomasses tend to be slow moving, allowing multi-species firms to exploit their informational advantage throughout the first weeks of the anchovy season.

On September 5, 2002, Alejandro Toledo, the President of Peru, signed a law banning mackerel from use in fishmeal or fish oil production, permitting it to be fished only for human consumption products (*El Peruano* 2002). Our rationale for treating the ban as an exogenous shock to firm scope is based on two factors. First, while government regulation of fisheries was already in place for two other species, anchovy and hake, it had never applied to mackerel before; thus, it is unlikely that firms avoided fishing for mackerel in anticipation of a mackerel ban. In fact, the law was issued as an executive order (*Decreto Supremo*) that press reports suggest was not widely anticipated. While there were a number of decrees issued to promote fishing for mackerel for human consumption after Toledo took office in July of 2001, the ban in question was not discussed in the legislature, and there is no mention of banning mackerel for fishmeal in any other executive orders related to the fishing industry. The first published mention of the possibility of a ban being put into place was in the small trade magazine, *Pesca*, in June of 2002 (Bermejo 2003), just three months before the ban went into effect in September 2002.

Second, while the bans on anchovy and hake were limited to a few crucial months in the species' biological cycles in order to protect their juvenile populations, the mackerel rule was applied to the entire year and in perpetuity. Thus, the ban created an exogenous and permanent (at least to the present time) reduction in firm scope.

Figure 1 shows the impact of the ban on mackerel fishing graphically. From January 1999 until just prior to the ban on mackerel, hundreds of thousands of tons of mackerel were extracted by Peruvian firms fishing for fishmeal in most quarters. After the ban, mackerel fishing for fishmeal was eliminated. We exploit the natural experiment provided by the mackerel ban to investigate the causal effects of a reduction in firm scope on activity-level performance.

4. Applying the theory to the context

Our proposition linking interdependence and performance in multi-activity firms in Section 2 is quite general. Conceptually, our framework applies to almost every reduction in the scope of a firm's activities, be it a product-line rationalization, asset sale, outsourcing decision or spin-off, as long as there is meaningful activity-level interdependence and organizational rigidity. However, because activity-level performance is often hard to observe and scope decisions are endogenous, the "true" effects of interest may often be hidden in the data. In this section we study which conditions have to be met for one to be able to predict a sharp empirical pattern in the data, and interpret finding such a result as evidence for our

proposition. One key insight is that we should see a swift drop and then subsequent improvement in activity-level performance, as long as that activity enjoyed net positive interdependencies just prior to the reduction in scope. Furthermore, by introducing activity-level rigidity an even stronger statement is allowed: performance will fall immediately and then rise again in the longer-run, if and only if the activity system is characterized by positive and negative interdependencies and organizational rigidity.

To fix ideas, consider two ways of organizing a firm, as a multi-activity firm with two activities, $a=\{1,2\}$, or as a single activity firm, $a=\{1\}$, where total firm profits Π are equal to the sum of each activity's profit, Π_i , less a fixed cost, F , which does not vary if activity 2 is added to the firm. In turn, each activity's profit, is equal to its stand-alone profit-level, π_i , plus, any activity-specific net positive or negative interdependencies, C_i , where $C_1 + C_2 = C_{1,2}$, and $C_1 + C_2 = C_{1,2}=0$ in single activity firms:

$$(1) \quad \begin{aligned} \Pi &= \Pi_1 + \Pi_2 - F = \pi_1 + \pi_2 + C_{1,2} - F, \\ \Pi_i &= \pi_i + C_i, \\ C_i &= C_i^+ + C_i^-. \end{aligned}$$

Clearly, in expression (1), interdependence effects, C , can be a key driver of the activity scope decisions, and, in general, the larger the total net positive interdependency, the more likely the firm will adopt activity 2.³ A net positive total interdependency, $C_{1,2}$, does not necessarily imply that each activity is made better off by the interdependency, however. Indeed, strategy is often about managing the tradeoffs inherent in interdependencies between activities, making sacrifices along one dimension to create positive interdependencies along another (Rawley and Simcoe 2010, Kumar 2014), such that C_i may be negative for any given i , even when $C_{1,2}$ is positive. Thus, a reduction in firm scope will lead to positive activity-level performance changes whenever there are net negative activity-specific interdependencies, $C_i < 0$, and would lead to negative performance changes whenever there are net positive activity-specific interdependencies, $C_i > 0$. We state this relationship as:

Hypothesis 1: When a focal activity enjoys activity-specific positive interdependencies, a reduction in firm scope leads to a decline in contemporaneous activity-level performance.

³ Conceptually the difference between activity-level interdependence and fixed asset utilization (Wernerfelt and Montgomery 1988) is clear: the former affects the profitability of scope through C , while the latter influence firm scope through F . However, as a practical matter separating these effects may be challenging. Fortunately, in our context the effects of fixed asset utilization in multi-activity firms (i.e., sharing a fishing boat across activities), can be easily dealt with (i.e., by focusing on performance during anchovy season).

If there are any negative interdependencies and firms are rigid in the sense that they not able to instantaneously adapt in the short-run (Hannan and Freeman 1984), but are adaptable in the long run, then activity performance will improve over time. Thus, we will observe falling and then rising activity-level performance, if and only if: (a) there are positive and negative activity-specific interdependencies, and (b) organizations are rigid, but adaptable, which we summarize as:

Hypothesis 2: In the presence of activity-level rigidity, contemporaneous activity-level performance will decline initially and then improve over time following a reduction in firm scope, if and only if there are both positive and negative activity-level interdependencies.

The logic for Hypotheses 1 and 2 lead to testable predictions about performance pattern of a firm that refocuses its activity system. If the evidence is consistent with these predictions it would be strong evidence for our Proposition 1 that interdependence creates both costs and benefits, but that costs are more persistent when the firm reduces its scope of activities.

Figure 2 illustrates the link between the key assumptions and the expected outcomes, by showing four sets of predictions of activity-level performance following a reduction in firm activity scope under four different sets of assumptions. Panel A represents performance when there are no interdependencies. Refocusing is a non-event in this case. Panel B shows the performance pattern when there are positive activity-level interdependencies, but firms are perfectly rigid. In this case negative interdependencies cannot be detected because performance falls following the refocusing and does not recover. In Panel C we show the performance pattern for flexible firms with only negative interdependencies *ex ante*. Performance improves to a steady state level immediately following a reduction in scope because only negative interdependencies are eliminated. Finally in Panel D we illustrate our predictions: performance will fall immediately following the ban, and then recover later. This signature performance pattern is at the heart of our hypotheses because it demonstrates the connections amongst firm activity scope, interdependencies, organizational rigidity, and performance.

While the theory offered in Section 2 is conceptually general, the analysis developed in this section makes clear that in order to take the predictions of the theory to the data three key conditions must be met for the above hypotheses to be valid. First, there must be both positive and negative interdependencies associated with the focal activity. Second, there must a meaningful level of rigidity in the firm's activity system. And third, positive interdependencies lost from eliminating an activity must be at least as large as any costs that can be instantaneously eliminated from refocusing. The first two conditions are, of course, exactly the general conceptual constructs we develop from the general theory. If either of the first two

conditions were violated, the theory would not apply to the empirical context. The third condition is a context-specific condition that makes the analytical model tractable. Violation of the third condition would not invalidate the theory, but would lead us to reject the hypotheses. Below we test each of these conditions explicitly in our empirical context.

5. Data and measures

5.1 Data and sample

Our data come from the Peruvian Ministry of Production's Fishing System proprietary database on fishing ships and fishing activity from 1999 to 2005. The Ministry collects mandatory daily reports on each fish purchase and transaction in the country, covering all fishing trips and catch size by species and weight for each fishing ship in the Peruvian Pacific Ocean. The Ministry also records ship characteristics, such as ship storage capacity and company affiliation for each fishing boat. Our tests are based on weekly data on the weight and type of all fish for fishmeal caught during anchovy season from the full set of 1,022 ships from 453 firms that reported fishing for fishmeal at least once during the sample.

The unit of analysis for the empirical tests is the ship-week for a single activity: anchovy fishing. Table 1 provides summary statistics on ship-week, ship and firm variables, as well as the correlations between the ship-week variables employed in the analysis. The table reveals substantial heterogeneity in productive factors and firm boundaries, which underscores the importance of using micro-data when studying the effect of firm scope on performance (Villalonga 2004). The average weekly tonnage of fish caught by a ship in our sample is 274 tons, and the standard deviation is 329 tons, though distribution of catches is very broad: from 0.04 tons to 3,120 tons. There is also substantial heterogeneity in the holding capacity the ships in our data set. The mean hold of a ship is 183m³, but the broad average includes small fishing boats with 8m³ holds to enormous ships with 868m³ of storage capacity. Ships in our data go on 3.41 fishing expeditions ("trips") per week on average. At the firm level, the smallest firms have but one ship, the largest have 61 ships and the average firm operates 2.4 ships. 41% of the firms were multi-activity firms, in the sense they had at least one ship that fished for mackerel for fishmeal in the pre-ban period. Regarding the correlation matrix, the key variable of the study, *REFOCUS*, is a difference-in-difference regressor, as will be explained below, so it is the product of two other variables described in Table 1. Importantly, the variance inflation factor of the independent variables employed in the regression analysis is 2.73 or smaller, suggesting that multicollinearity is not a concern in our design.

We estimate the impact of a reduction in firm scope on activity-level performance using a difference-in-differences estimator. This methodology compares the within-ship changes in productivity of ships in multi-activity firms, before and after the mackerel ban, against within-ship changes in productivity of single-activity firms, controlling for secular changes in productivity at a very granular (weekly) level.

Across many industries, under certain assumptions, changes in productivity map directly to changes in profitability; for example, when firms are price-takers and production is characterized by constant returns to scale, including any unobserved fixed costs (e.g., back office administrative costs), productivity maps directly to profitability. In anchovy fishing for fishmeal, the link between productivity and profitability is direct, as companies sell an undifferentiated product at a market price that they cannot influence given the atomized industry structure. Analytically, the link between productivity and profitability can be more easily noted by defining the profit function in the usual way with two parameters that link profitability and productivity to the firm activity scope and to the periods before and after the ban. Profit π for an input and output price-taking firm j , in business-segment $s = \{\text{anchovy, mackerel}\}$, can be represented by:

$$(2) \quad \pi_j = (p_a - c_a)Y_{ja}(\theta, \sigma) + (p_m - c_m)Y_{jm}(\theta, \sigma) - F(K_j),$$

$$Y_{js} = A_{js}(\theta, \sigma)K_{js}^{\beta k}L_{js}^{\beta l},$$

where Y is output in tons, subscripts a and m index anchovy and mackerel operations; $F > 0$ is the (unobserved) fixed cost of operations, where fixed costs are increasing in total capital deployed (K). The market price per ton $p > 0$ and the marginal cost of harvesting an additional ton $c > 0$ convert physical output into gross profit, where physical output Y is generated by a production function that transforms capital (K) and labor (L) using technology (A), which can be interpreted as total factor productivity in quantities, TFPQ.⁴ The two key parameters $\theta = \{0, 1\}$ and $\sigma = \{0, 1\}$ index when the firm is operating—before or after the ban—and whether the firm is a single-activity or multi-activity entity, respectively, thus fully capturing the impact of positive and negative interdependencies as discussed above.

It is clear from expression (2) that when firms are price takers, as they are in our setting, all the variation in activity-level profitability within and between firms must flow through the production functions or through fixed costs. If production and fixed costs exhibit constant returns to scale (CRS), then changes in TFP completely drive changes in profits in expression (2). We verify that the anchovy production function is approximately CRS at the firm and ship level, but acknowledge that we have no way of knowing if the CRS assumption might be violated with respect to other fixed costs that we do not observe. However, even if fixed costs do not exhibit CRS precisely the mapping between our conceptual measure (profitability) and our empirical measure (productivity) of activity-level performance appears to be quite close.

⁴ TFPQ is similar to, but superior than, revenue-based measures of total factor productivity TFP, which may be biased by heterogeneity in prices (e.g., as in the production of differentiated goods). Our estimates of outputs (Y =tons of fish) and inputs (K =capacity x trips) are in quantities, thus, we are estimating the impact of a reduction in firm activity scope on changes in TFPQ. We describe the TFPQ estimation approach in more detail in an appendix.

For the purposes of testing for the effects of a change in activity scope on interdependence effects, productivity-based measures of performance will generally be superior to market- and accounting-based measures of activity-level performance, because productivity-based measures filter out accounting allocations and market fluctuations. In certain other contexts, particularly in cross-sectional comparisons of producers of differentiated goods, productivity will not be as useful compared to accounting-based measures. Also, because productivity is backward looking, rather than forward looking, it is not very informative about future expectations, as are market-based measures of performance (e.g., Markides 1992). However, because the theory makes predictions about contemporaneous operating effects of interdependence, stock-market-based measures of performance, which conflate current profitability with future, expected profitability, would not be ideal for testing our theory.

Our main sample frame begins on January 1, 1999 and continues through December 31, 2003, so that we have 44 months of pre-ban observations and sixteen months of post-ban observations on which to base our statistical estimates. We only consider weeks during the anchovy fishing season, determined by the Peruvian government, totaling 139 weeks. We explored a number of alternative sample frames including using symmetric pre-ban and post-ban periods, and found that our results were robust to a pre-ban period of any length. As we describe below, increasing the post-ban sampling period does not change the statistical significance of our results, but does influence the economic magnitude of the effect over time, consistent with our conceptual framework.

5.2 Baseline measures

The dependent variable in our analyses is the log of tons of fish (anchovy) caught per week by ship, which is reported directly to the Ministry.⁵ Our main explanatory variable is a dichotomous time-varying firm-level variable, *REFOCUS*, which captures whether the ban on mackerel fishing forced a firm j to reduce the scope of its operations in week t .⁶ $REFOCUS_{jt} \equiv BAN_t \times MULTI_j$, where BAN is equal to one in all periods following the mackerel ban, and zero before the ban, and $MULTI$ is equal to one if firm j had at least one boat that fished for mackerel for fishmeal before the ban, and is zero otherwise. The operational scope of the firm in this study is based on activities performed in the extraction phase of the industry, as opposed to vertical scope between upstream extraction and downstream marketing and

⁵ Fishmeal and fish oil can include more than 35 different species of fish, such as catfish, Pacific menhaden and flying fish. However, during anchovy season, anchovy represents more than ninety-five percent of all catches (by weight). We measure productivity in anchovy fishing during anchovy season. Our results are robust to including other species in our measure of output.

⁶ The choice of a dichotomous time-varying variable to study firm scope is rooted in prior research on diversification (e.g., Villalonga 2004). We also employed a continuous variable capturing the degree to which each firm was active in mackerel fishing, and we found that our modeling choice was robust to that alternative proxy.

distribution processes, where interdependencies are arguably less tacit, and therefore less affected by changes to extraction processes. Our modeling choice for defining scope based on horizontal activities is also in line with fisheries research (e.g., Duarte 1992).

In addition to ship, time (week) and location fixed effects, our other key control variable is capital deployed k per ship i , per week t , where $k_{it} = \log(\text{ship-specific storage capacity} \times \text{number of fishing trips the ship takes per week})$. By controlling for the number of fishing trips per week in our measure of capital, our measure of productivity is robust to variation in the intensive margin of asset utilization, and captures only the performance of the essential activity of interest: the efficiency with which ships extract fish.

To measure the time path of productivity effects, we create categorical variables for each of the seven anchovy fishing seasons from the date of the ban (September 2002) until the end of 2005, where seasons are defined by the Peruvian fishing authority. We interact the season dummies with *REFOCUS* to capture the marginal effect of the ban on productivity over time by season. Later we discuss the measures associated with the (context specific) mechanisms operating behind the key effects we identify.

6. Empirical Specification

Because firms choose the scope of their activities, a well-identified test of the impact of a change in firm activity scope on performance requires exogenous variation in the scope of the firm. We are fortunate to have such a shock in this study in the form of the mackerel ban of 2002 that led to a reduction in the number of species firms could extract from the sea. The Peruvian regulatory ban completely eliminated mackerel fishing for fishmeal in September 2002. Thus, our “treatment” group is the set of firms that were formerly multi-activity firms—firms that fished for both anchovy and mackerel. Because mackerel and anchovy are extracted in serial, rather than in parallel, in our context, the reduction in scope primarily influenced inter-temporal interdependencies. Our “control” group is all other firms that remain focused on a single activity—anchovy fishing—throughout the sample, which allows us to control for secular changes in productivity with a difference-in-differences approach. Controlling for secular effects is particularly important in this study because of our focus on inter-temporal interdependence; biomass levels can vary dramatically from season to season and even week to week, generating noise which could easily swamp the information in a simple event-study research design.

Our first hypothesis predicts that a reduction in firm activity scope will lead to a drop in the productivity of the firm’s remaining activities when there are positive interdependencies between activities. To test Hypothesis 1, we develop an econometric model of scope and performance that captures the effect of a reduction of firm activity scope on productivity, relative to changes in the productivity of other firms that were not directly affected by the shock, where i indexes ships, and t

indexes weeks, y is log tonnage of fish extracted from the ocean, k is the log of the ship's capacity (storage capacity x trips/week), λ is a ship fixed effect, T is a week fixed effect, and G is a fishing zone location fixed effect.

We estimate the effect of a reduction in firm scope on activity-level performance based on the standard approach for measuring total factor productivity. However, importantly, we do not observe labor in our data, which would be a serious limitation in many industries. Fortunately, in the Peruvian fishing industry, according to our interviews with ship captains and industry executives, the minimum number of workers per ship is fixed by regulation based on the physical characteristics of the ship, and in practice ships tend not carry more workers than what is required by law. Thus, in this context, ship-level production is a classic Leontief case—within-ship capital and labor are used precisely proportionally over time—assuaging concerns about measurement error. Therefore, for any given ship, we can rewrite our activity-specific production function as:

$$(3) \quad y = a + \beta_k k,$$

where y the natural logarithms of the tonnage of anchovy extracted, k is the natural logarithm of capital deployed, and a represents TFPQ.

We estimate the percentage change in a firm's activity-level productivity from a reduction in activity scope, using a difference-in-differences estimator by including 1,022 ship fixed effects λ_i , 139 week fixed effects T_t , and four location fixed effects G_{it} , along with the explanatory variable $REFOCUS_{jt}$, as in:

$$(4) \quad y_{it} = \alpha + \beta_k k_{it} + \beta_R REFOCUS_{jt} + S_{it} + \lambda_i + T_t + G_{it} + v_{it}.$$

To distinguish changes in firm activity scope from changes in firm size (e.g., Henderson and Cockburn 1996), we include time-varying size quintile dummies S_{it} in the specification, based on the number of ships each firm has each fishing season, though in practice we find that firm size controls have little impact on the results. Standard errors are robust and clustered at the firm level.

Productivity is highly volatile over time, even within ship, based on the natural variation in the abundance of the sea, but the average residual over time v_{it} must be zero for all ships. Thus, the coefficient on $REFOCUS$, β_R , in (4) estimates within-ship changes in productivity from a reduction in firm activity scope relative to within-ship changes in productivity in firms that did not change their scope.

Specification (4) controls for all sources of time-invariant ship-level heterogeneity and also for changes in the intensive margin within-ship (i.e., variation in weekly ship utilization), all factors that influence ship productivity in common over time (i.e., time-varying marginal productivity of capital and

labor) perhaps due to weather and the abundance of fish in the sea at a point in time or in a particular location. Thus, β_R can be interpreted as the percentage change in the real productivity of a firm's anchovy extraction activities due to the elimination of its mackerel extraction activity, which is precisely the empirical measure we want to test our theory. However, one minor drawback of this estimation approach is that, mechanically, firm productivity cannot increase for one group (e.g., the multi-activity firms) unless it falls for another group (e.g., focused firms), as productivity is measured as a group-level difference, net of ship and time-specific effects.

An alternative specification is needed to estimate the persistence of a negative productivity shock following refocusing. To test the second hypothesis we extend specification (4) by including the full set of *REFOCUS* \times *SEASON* dummies in our rigidity tests. By construction, the *REFOCUS* \times *SEASON* dummies capture the time path of organizational rigidity and adaptation after the ban.

Our empirical approach deals with measurement error, and the endogeneity of firm scope, which have been major barriers to progress in studies of scope and performance. Indeed, our tests form a valid basis for causal interpretation of whether the effect of the change in scope operates through a decline in TFPQ, the marginal productivity of capital (i.e., of each trip) and/or the marginal productivity of labor in formerly multi-activity firms relative to single-activity firms. As our main interest is with the effect of the change in scope on activity-level performance any or all of these channels satisfy our theory. However, it is particularly important to understand whether changes in the marginal productivity of capital are economically meaningful in this context. For example, if formerly multi-activity firms shifted their fleet distribution strategy away from taking long trips that filled up ships to capacity with anchovy before the ban, toward taking many short trips that resulted in less-than-full capacity catches after the ban, β_R will overstate (negatively) the true economic impact of the change in scope because of the relationship between capacity utilization (catches/trip) and β_R . On the other hand, if the ban results in less efficient searching for anchovy in formerly multi-activity firms, β_R will appropriately capture both a decline in TFPQ, and a real economic decline in the marginal productivity of capital, caused by the reduction in firm scope.

We take three approaches to disentangle changes in real productivity from measured changes in productivity. First, we control for weekly changes in the marginal productivity of capital directly in specification 2.2 below. Second, we exploit the fact that anchovy is subject to frequent temporary (e.g., a few days long) fishing moratoriums determined by the Peruvian government during the fishing season (*El Peruano* 1992). In an additional specification, we instrument for the number of trips component of k_{it} using the number of unrestricted anchovy fishing days in each geographical location in each week. This instrument is exogenous to the actions of a given ship or firm, and it satisfies the exclusion restriction because regulatory restrictions on anchovy are imposed based on biological considerations (e.g., early

spawning, late migration, etc.) that should be otherwise uncorrelated with the marginal productivity of a trip relative to other ships. Although the instrument only varies at the fishing zone-week level, not the ship-week level, it can be expected to generate a strong first stage because the off-season prohibitions on fishing for anchovy lead firms to maximize ship utilization (i.e., productive fishing time at sea) during the fishing season. To wit, fishermen call anchovy season “the Olympic race” because of the frenzied activity that begins with the opening of the season. Therefore, the temporary moratoriums should be a binding constraint with respect to ship utilization and firms should utilize their ships more heavily in the absence of such restrictions. Finally, we examine the change in the number of trips per ship to infer whether trip durations lengthen or shorten after the ban for formerly multi-activity firms relative to single-activity firm. This last test is particularly important because, if trips lengthen after the ban, it not only gives us a clearer picture of real productivity effects; it also gives us some insight into the mechanism behind organizational rigidity. Longer trips during the fishing season imply lower ship utilization per unit of time, during a period when time is of the essence, suggesting that formerly multi-activity firms’ ship distribution practices are a key source of rigidity.

7. Results

7.1 Baseline results

Figure 3 previews our baseline results. The plots show firm anchovy-specific productivity distributions in kernel densities for multi-activity and single-activity firms before and after the ban on mackerel, (excluding the top and bottom 1% of the productivity distribution). The top panel reveals that before the ban, the productivity distribution of firms that fished for both anchovy and mackerel was very similar to the productivity distribution of ships in firms that focused on a single activity. Following the ban, the relative position of ships in formerly multi-activity firms has shifted to the left (downward) relative to ships in single-activity firms.

Table 2 provides further evidence on the effect of reducing firm activity scope on anchovy productivity in multi-activity firms relative to single-activity firms. Column 2.1 shows the pooled cross-sectional estimate of the ban on ship-level productivity for firms that were previously multi-activity. The coefficient on *REFOCUS*, which represents the average (relative) change in productivity of ships in multi-activity firms, is -21% and precisely estimated. The coefficient on k_{it} in this regression is 1.05, which suggests slight (5%) economies of scale at the ship level. In column 2.2 we include ship fixed effects to control for time-invariant ship-specific heterogeneity and allow the marginal productivity of capital to vary by week replacing k_{it} with the interaction term $k_{it} \times T_t$. The coefficient on *REFOCUS* is similar at -20% and precisely estimated, though the interpretation is now more robust: *REFOCUS* represents the within-ship change in anchovy productivity for formerly multi-activity firms relative to

single-activity firms, controlling explicitly for time-varying marginal productivity of capital. Including ship and year-week fixed effects in column 2.3 delivers within-ship estimates of changes in productivity for ships in formerly multi-activity firms relative to single-activity firms controlling for all sources of common (i.e., weekly) variation in productivity. Controlling for all sources of common variation has a slight effect on the coefficient on *REFOCUS*, which falls to minus 16%, but is still precisely estimated. To put the economic magnitude of the effect in perspective, at the ship level, a 16% drop in productivity translates into approximately a 44-ton reduction in fish caught per week or 13% of one standard deviation of output, amounting to about \$75,000 in lost revenue per ship per year.

The coefficient estimates on k_{it} in the presence of ship and week fixed effects can be interpreted as the average within-ship marginal productivity of an incremental trip. Unsurprisingly, given the regulatory restrictions on anchovy season, the marginal productivity of an incremental trip is large at 1.25, which means a 1% increase in the number of trips leads to a 1.25% increase in catches. Thus, one can see that ship utilization is a choice variable only in a limited sense. If the marginal trip is valuable, firms will attempt to maximize capital utilization, and any failure to do so should properly be considered a real performance effect. However, our baseline results treat ship utilization as an exogenous control variable; therefore, the results in column 2.3 can only be interpreted as evidence of a productivity effect before considering endogenous capital utilization.

To clarify this issue, column 2.4 shows the results of a two-stage least squares (2SLS) estimation that addresses the endogeneity of capital utilization. Instrumenting for k_{it} using the number of days without restrictions on anchovy fishing in week t by fishing zone reveals that the absence of temporary restrictions is a strong predictor of capital utilization. The coefficient estimate on the instrument is positive and precisely estimated in the first stage of the 2SLS model with a t-statistic of 17. The F-statistic is 291 and the R^2 is 0.81, which suggests that the instrument is powerful. After instrumenting for capital utilization, the coefficient on *REFOCUS* in the second stage is larger and significantly different from the baseline estimates at -24%, and is statistically significant at the 1% level. The interpretation of the 2SLS result is that firms responded to the ban by changing their ship distribution practices to be more in-line with practices in anchovy-only firms, which leads to an underestimate of the causal effect of refocusing on productivity in column 2.3.

The overall message of Table 2 is that the reduction in firm activity scope brought about by the ban on mackerel fishing for human consumption led to an economically and statistically significant drop in anchovy productivity in firms that were formerly multi-activity relative to firms that had always been focused on anchovy. Because firms chose to enter into mackerel fishing prior to the ban, we cannot claim that refocusing would have had the same economic impact on firms that were never engaged in multiple

activities. However, conditional on fishing for mackerel before the ban, the results show that refocusing hurt anchovy productivity.

The results are easy to interpret in Table 2 because a single coefficient summarizes how the shock to firm scope influenced performance on average. As a practical matter, though, the underlying variation in productivity is more nuanced, and complicated to display visually at a more disaggregated level (i.e. compared to Figure 3) because productivity is only meaningful within-ship, within-zone, de-trended, relative to firms of a different type. Nevertheless, Figure 4 represents one effort to display the data graphically, showing average weekly “productivity” residuals from a variation on expression (4) that excludes the *REFOCUS* and the weekly fixed effects. One can clearly see in Figure 4 that the ban was associated with a stark divergence in the productivity of ships in multi-activity relative to single-activity firms.⁷ Figure 4 also shows some season-specific productivity effects by firm type (i.e., multi-activity or single-activity), which we discuss in more detail as both a plausible proximate explanation for the strong rigidity effects we find (in the discussion section 6.3), and as a potential threat to causal inference (in the robustness checks section 6.4) below.

To test whether the negative productivity shock associated with reducing the activity scope of the firm attenuates over time, we extend the post-ban treatment period to the end of the data set (2005) and examine how the productivity effects change by season. Table 3 shows two versions of the test. Column 3.1 extends our core sampling frame from 1999 to 2005, and measures the effect of a scope reduction on productivity over a longer time period than in the baseline estimates 1999-2003. Column 3.2 modifies the main specification, unpacking *REFOCUS* into interactions of *MULTI* with seven season dummies, one for each season after the ban. The results reveal that the negative productivity shock associated with reducing the scope of the firm attenuates over time, falling to -7% from -16% with the addition of two additional years (column 3.1).

Column 3.2 shows the attenuation effect by season. In the first three seasons following the ban, the point estimates of the productivity effect are in the 14-20% range and precisely estimated; however, after the fourth season post-ban the point estimate of effect of the reduction in firm scope is indistinguishable from zero. The sudden improvement in productivity in the fourth season may reflect a learning effect—it took formerly multi-activity firms some time to realize their legacy procedures, particularly ship distribution practices, were outmoded under the new regulatory regime. Thus, given the empirical

⁷ In the presence of substantial exogenous idiosyncratic period-specific productivity shocks the *level* of the residuals in Figure 4 are uninformative, only the *difference* between average productivity residuals is meaningful. Moreover, mechanically in this specification, productivity can only increase for one group if it falls for another. Thus, Figure 4 does not suggest that productivity increased in single-activity firms and fell in formerly multi-activity firms, only that single-activity firms were relatively more productive after the ban compared to the formerly multi-activity firms.

context, it is not surprising that we see non-linearities in firms' adaption processes. Furthermore, our main interest in studying performance dynamics on a season-by-season basis is simply to establish that organizational rigidity and negative interdependencies are economically and statistically important following a reduction in firm scope—the theory does not make sharp predictions about the exact time path of rigidity and adaptation. Still, we would like to further investigate the particular context-specific mechanisms behind all three of our key concepts—positive interdependencies, negative interdependencies and organizational rigidity. In the next sub-section we examine two extensions that shed more light on how activity interdependence influences productivity after refocusing.

7.2 Mechanisms

Positive informational interdependencies between anchovy and mackerel fishing suggest a larger decline in activity-level performance for firms that gathered more information about anchovy while fishing for mackerel. Counting the number of times firms switched back and forth their operations between anchovy and mackerel offers a useful proxy for how much information firms obtained about anchovy while fishing for mackerel. We measure the number of switches by constructing a variable, *SWITCHES_j*, which is equal to the number of times a firm switched from fishing for anchovy to fishing for mackerel or vice versa. To facilitate a straightforward interpretation of *SWITCHES*, we normalize the measure to be mean zero and have a standard deviation equal to one at the firm level. Supporting the idea of *ex ante* positive interdependencies between activities, Table 4, column 4.1 shows that when firms switched between mackerel and anchovy more frequently, they experienced larger anchovy productivity declines post-ban. The coefficient on the term *REFOCUS* \times *SWITCHES* is -0.14 and is significant at the 1% level. The interpretation is that a one standard deviation increase in *SWITCHES*, or 7-8 additional changeovers per season per firm, was associated with an additional 14% decline in productivity, relative to a baseline rate of -16% in all firms that were forced out of the mackerel business.

One interesting implication of informational interdependencies between mackerel and anchovy fishing is that multi-activity firms distributed their ships differently than single-activity firms. Instead of sending ships to the most heavily fished waters closer to the shore, multi-activity firms sent ships to smaller, more distant shoals where the fishing boats faced less competition. If ship distribution processes were indeed rigid, we would expect that trip lengths would lengthen for formerly multi-activity firms, relative to single-activity firms, as ships in formerly multi-activity firms would engage in more time-consuming search efforts *ex post*. Therefore, if ship distribution practices are an underlying driver of organizational rigidity, we should see that the number of trips per ship falls in formerly multi-activity firms relative to single-activity firms after the ban. Table 4, column 4.2 shows evidence in favor a trip-length mechanism statistically using log trips as the dependent variable. We see that trips per ship per

week fell by 15% in multi-activity firms after the ban relative to single-activity firms. This key result suggests that after losing the information about the location of anchovy shoals gained when fishing for mackerel, formerly multi-activity firms were spending more time searching for anchovy post-ban, which led to longer trips. Taken together with the productivity result that shows increasing returns to utilization during the anchovy season, the trip-length effect suggests that inefficient capital utilization due to organizational rigidity at the routine level was an important part of the reason the ban on mackerel fishing caused anchovy performance to fall in formerly multi-activity firms.

7.3 Robustness checks

At a glance Figures 4 and 5 both raise the question of whether the three seasons of poor performance for formerly multi-activity firms we document is just a spurious correlation with the enactment of the mackerel ban. The fact that formerly multi-activity firms suffered three straight seasons of poor performance following the ban when they had not experienced even two consecutive seasons of negative differential productivity suggests otherwise. Placebo tests of the treatment in periods before the ban corroborate this intuition. More authoritative econometric evidence that the ban caused the productivity effect is shown in Table 5 where we introduce ship-specific linear trends to account for any unobserved micro-organizational time trends at the moment of the shock. The coefficient estimate is slightly smaller, but is still negative and precisely estimated (column 5.4). We report a few other important further robustness tests in Table 5. First, we drop the tails of the productivity distribution to show that the results are not driven by outliers (column 5.1). To address concerns about whether the interdependence effect is actually operating vertically, instead of horizontally as we have claimed, by changing the productivity of firms who own downstream fish processing facilities, we eliminate these firms and find a similar result (column 5.2). As a validity check we leave in the sample only multi-ship firms—the firms one might expect to be most interdependent—and show that those are the firms driving the results (column 5.3). Finally, in untabulated models we find that the results are also robust to different *ex ante* sampling windows and to changing the design to aggregating observations at the firm level rather than at the ship level.

7.4 Discussion

This paper studies the effect of a change in scope on the performance of an interdependent activity performed by fishing boats. Since ships are essentially floating factories, and in that sense are quite similar to a wide range of operating environments, we expect that our results will generalize directly to other production environments. For example, our analysis would be useful to a bottler considering a scope reduction that would change the number of filling lines in the bottling plants, or a steel

manufacturer facing the question of whether to outsource metal cutting activities at the end of a metal rolling process. Moreover, the results are closely related to many other situations where a firm is considering a reduction in activity scope, for example when firms divest assets and redeploy resources (e.g., Capron, Mitchell and Swaminathan, 2001). Casual observation suggests that much of the economic activity within most firms exhibits some meaningful interdependence with another activity. Our approach highlights the role of interdependencies in firms that reduce their scope by outsourcing, spinning off, rationalizing or otherwise eliminating an activity that is “related” to other activities within the firm.

While our theory is quite general it is not universal. For example, it will not apply when interdependencies between activities are not meaningful, such as in many conglomerates. Another limitation of our conceptual approach is that we do not formally derive an equilibrium theory of scope and performance; rather, we assume scope decisions will generally be rational and develop our theory logically from that precept. However, it is fair to note that other research on endogenous spinoffs has attributed a similar empirical pattern to systematic managerial mistakes (Feldman 2014). While the exogeneity of refocusing in our setting rules out scope reduction mistakes our empirical context, we do not claim that mistakes never happen. Thus, strategy research on refocusing would benefit from endogenizing the decision to reduce firm scope, and formally tying the results of an equilibrium model of firm scope directly to the impact of interdependencies on contemporaneous performance. A third limitation of this research is that we only observe the change in productivity of one activity. It would be quite interesting for future scholars to study the impact of a reduction in scope on activity-level performance in a context where the performance of multiple interdependent activities could be tracked over time.

One of the major advantages of our empirical approach is that we study productivity effects when firm scope is exogenously reduced. But most decisions to sell a division, or shut down a product line or a practice are the result of a choice by a CEO or a management team, not the result of regulatory fiat. So one might reasonably ask, what can the results tell us about endogenous changes in firm scope? Our key proposition—that interdependence simultaneously creates costs and benefits, but that costs are more persistent when the firm reduces its scope of activities—will hold whether refocusing is endogenous or exogenous. Though the empirical results were obtained in a natural experiment context, the conceptual basis for our proposition, and all of its implications, apply more generally. The context-specific prediction that would be difficult to test empirically, in a context where firm scope was reduced endogenously, is the idea that shedding an activity will lead to an *immediate* reduction in contemporaneous performance. Indeed one might expect that typically performance will improve when a firm refocuses, precisely because management would not choose to refocus the firm if they thought it would harm performance. Yet, even when firms choose to reduce the scope of their activities, positive

interdependencies will be disabled, particularly for segments of the business that interacted the most heavily at an operational level with the jettisoned activity, and negative interdependencies will persist whenever organizations are rigid at the level of the interdependent routine. Thus, even when firms endogenously reduce their scope, the key ideas in this paper apply, though, of course, finding the signal in the noise is potentially more difficult when refocusing is endogenous.

The question about endogenous changes in firm scope leads naturally to questions about why firms do not adapt instantaneously, or at least very quickly, following a change in firm scope. While an in-depth study of the origins of organizational rigidity is outside the scope of this paper, the question is relevant because the concept of organizational rigidity is central to our theoretical framework. We find evidence of organizational rigidity at the level of the sub-activity—firms did not immediately adapt their ship deployment practices and took several seasons to regain their pre-shock productivity levels—but we do not know the root cause of why firms are rigid in the first place. There are many plausible sources of organizational rigidity—time compression diseconomies, causal ambiguity, limited information, cognitive limits—but our data is not rich enough to distinguish definitively between competing explanations.

While we do not wish to speculate extensively on the origins of organizational rigidity, Figure 5 does offer some suggestive evidence. In the figure we plot the regression coefficients on *REFOCUS* season by season for all formerly multi-activity firms, which is a graphical representation of the specification of model 3.2 in Table 3, but with the eight seasons before the ban included as well. The vertical axis is differential productivity, where the baseline differential productivity effect is zero, measured relative to the control group of ships in firms that never engaged in multiple activities. Two observations are striking from Figure 5: productivity is volatile, and season-specific productivity effects are strong. Before the refocusing ban, multi-activity firms in the anchovy business were sometimes better, sometimes worse than single-activity firms. After the refocusing ban, formerly multi-activity firms did poorly for three consecutive seasons before finding a more stable level of productivity. But given the historical volatility in productivity one might speculate that it may not have been obvious to firms that their legacy practices were hurting their current productivity levels, which may suggest a link between rigidity and limited information/cognition.

While our inability to pin down the sources of heterogeneity in organizational rigidity more precisely represents a limitation of this research, it is also an opportunity for future scholarship. In particular one would want to know why some firms are able to adapt quickly to changes in firm activity scope while others delay longer.

8. Conclusion

This paper shows conceptually and empirically the performance effects of interdependencies in firms that reduce the scope of their activities. Using a simple analytical framework to connect the general theory to predictions that we take directly to the data, we make use of a shock to firm activity scope in the form of a regulatory ban on mackerel fishing in Peru, and find that removing an activity (mackerel fishing) from a firm's nexus of activities leads to a 16% decline in the productivity of the firm's remaining activity (anchovy fishing) in the short run (1.25 years). The negative productivity effect attenuates over time, suggesting that while organizations are rigid in the short run they are adaptable in the long run. The results are most pronounced for firms with the strongest interdependencies between activities. Moreover, rigidity is explicitly tied to a failure to adapt legacy processes at the time of the ban, suggesting that activities are so deeply embedded into organizations that they become tacit, and are, therefore, difficult to recognize as a potential source of inefficiency when the external environment changes.

Taken together the results provide new insights into the relationship between interdependence and firm performance in the context of firm scope. While firms appear to design their organizational systems to take advantage of positive interdependencies between activities, by replacing markets with hierarchies the firm also creates negative interdependencies that will tend to persist over time.

The findings have implications for scholars and practitioners alike. For strategy scholars interested in firm scope and performance, one key implication is that firm boundaries will reflect the benefits and costs of adapting the firm's activities. For example, expanding firm scope to take advantage of positive interdependencies will tend to make the firm more vulnerable to changes in the external environment. For practitioners the study offers a cautionary tale of the dark side of interdependencies, suggesting that it may be wise to prepare for the organizational costs of refocusing by coming to grips with the explicit rationale for interdependencies well before the change is implemented.

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Appendix: Estimating productivity effects

The standard production function with two inputs capital K and labor L is:

$$(A1) Y = AK^{\beta_k}L^{\beta_l}$$

When Y is a revenue-based outcome measure, A is total factor productivity, TFP, when physical output measure A is total factor productivity in quantities, TFPQ.⁸ Holding the ratio of capital and labor fixed⁹ and taking logs we can re-write (A1) as:

$$(A2) y = a + \beta_k k,$$

where variables written in lower case letters in (A2) are the natural logarithms of variables written in capital letters in (A1); for example a represents TFPQ.

If the marginal productivity of capital is constant over time for any given asset i , one can separately estimate the time-invariant and time-varying components of TFPQ. For example to estimate the time-invariant component of TFPQ λ_i , and time-varying component of TFPQ η_{it} , $TFPQ_{it} = A^{\lambda_i + \eta_{it}}$, one can estimate the following:

$$(A3) y_{it} = \alpha + \lambda_i + \beta_k k_{it} + e_{it},$$

where, t indexes time, $\lambda_i \equiv \lambda_i a$, $e_{it} \equiv \eta_{it} a$, and α is a constant.

Breaking $TFPQ$ down further into time-invariant λ , time-specific τ , location-specific Γ , scope-related ρ , scale related Σ , and idiosyncratic ε components we have:

$$(A4) TFPQ_{it} = A^{\lambda_i + \tau_t + \Gamma_{it} + \rho_{jt} + \Sigma_{it} + \varepsilon_{it}},$$

where j indexes firms.

We can estimate each component of $TFPQ$ in (A4) just as we did in the two component case (A3) using:

$$(A5) y_{it} = \alpha + \beta_k k_{it} + \lambda_i + T_t + G_{it} + S_{it} + \beta_R REFOCUS_{jt} + v_{it},$$

where, in our context, $\lambda_i \equiv \lambda_i a$ is a time-invariant ship-specific effect, $T_t \equiv \tau_t a$ is a week fixed effect, $G_{it} \equiv \Gamma_{it} a$ is a location fixed effect, $S_{it} \equiv \Sigma_{it} a$, $MULTI_{jt} \equiv \rho_{jt} a$ captures the effect of a reduction in scope on productivity, α is a constant, and $v_{it} \equiv \varepsilon_{it} a$ measures unexplained variation in $TFPQ$. Equation (A5) is the same as our empirical specification (5) above.

⁸ $TFPQ$ is similar to, but superior than, revenue-based measures of total factor productivity TFP , which may be biased by heterogeneity in prices (e.g., as in the production of differentiated goods). Our estimates of outputs (Y =tons of fish) and inputs (K =capacity x trips) are in quantities, thus, we are estimating the impact of a reduction in firm activity scope on changes in TFPQ.

⁹ Our interviews with ship captains and industry executives confirmed that ship-level production is Leontief in the Peruvian fishing industry. The minimum number of workers per ship is fixed by regulation based on the physical characteristics of the ship, and in practice ships do not carry more workers than what is required by law. Thus, within-ship capital and labor are used precisely proportionally.

Figure 1: Mackerel ban and mackerel catches

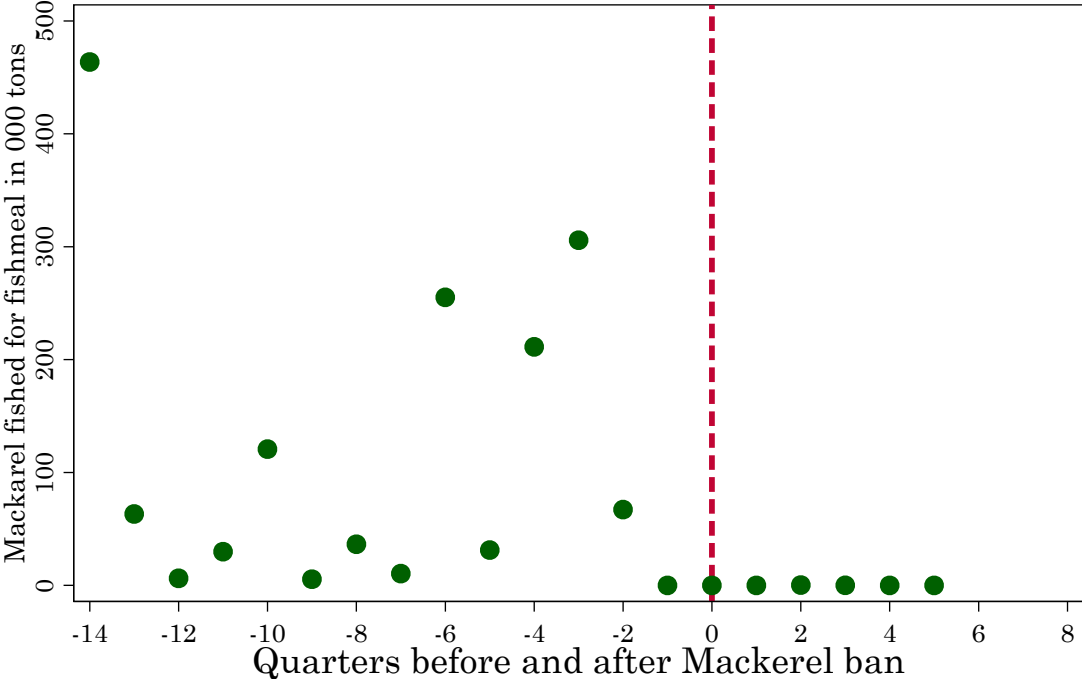
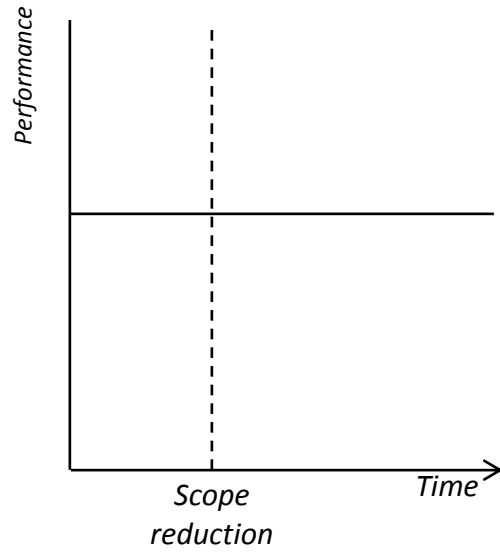
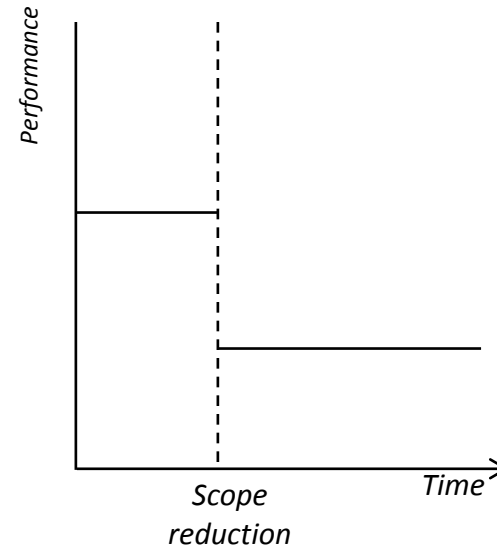


Figure 2: The Theory Illustrated

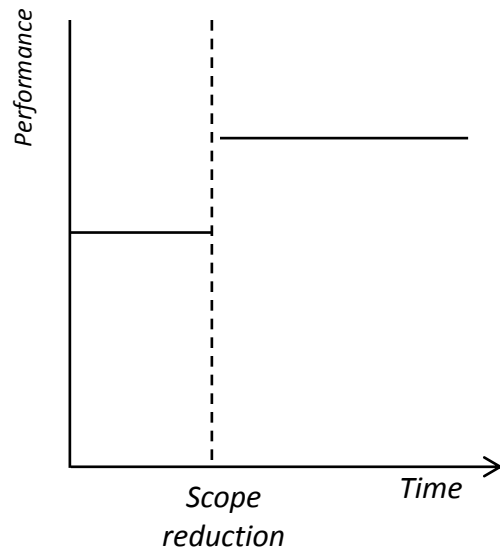
A. No interdependencies



B. Positive interdependence and fully rigid



C. Negative interdependence



D. Interdependence; rigid, but adaptable firms

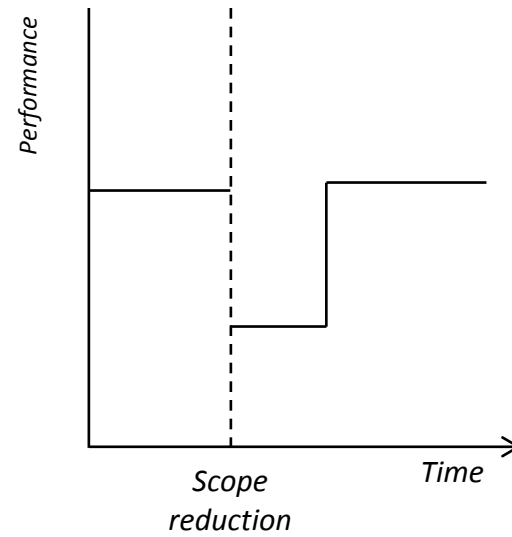
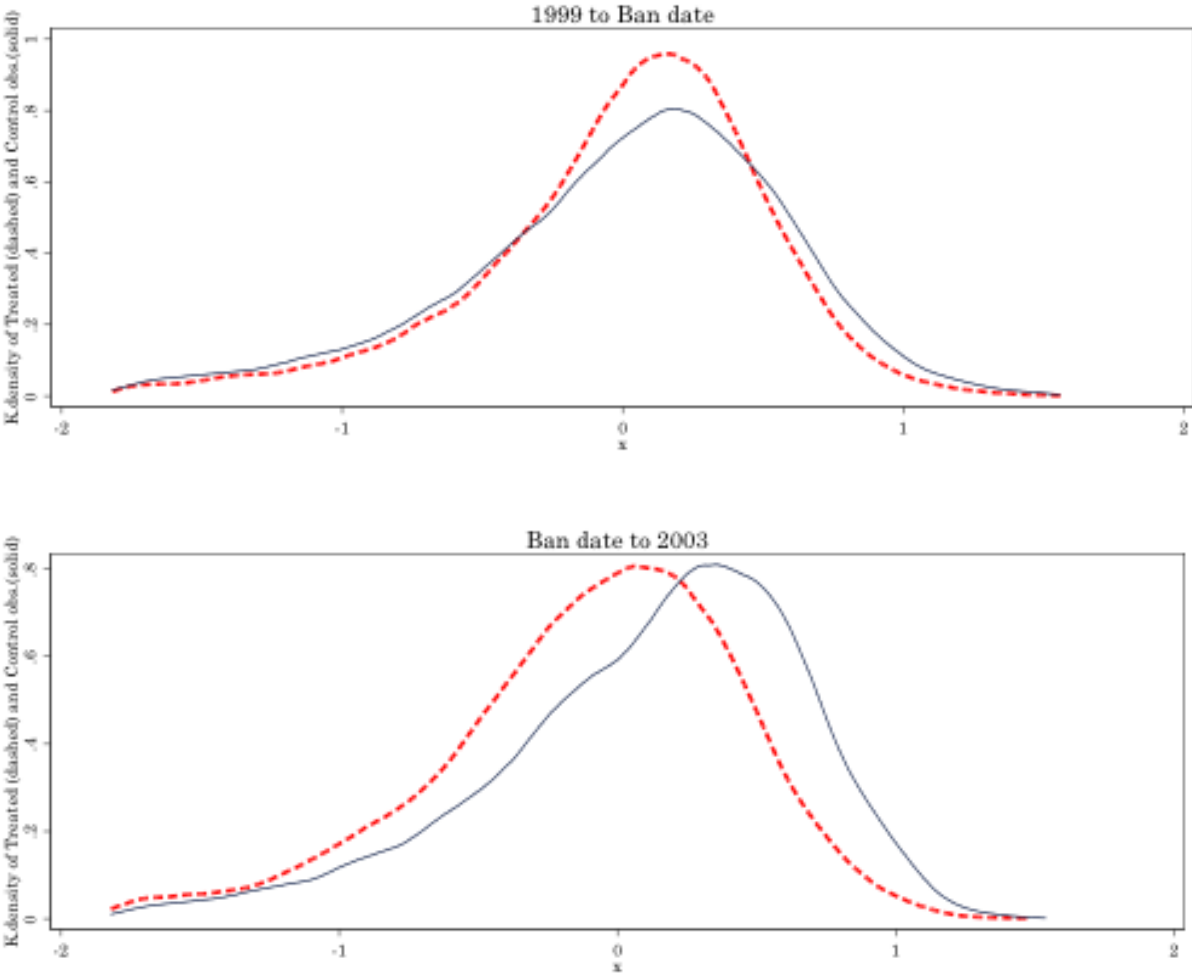
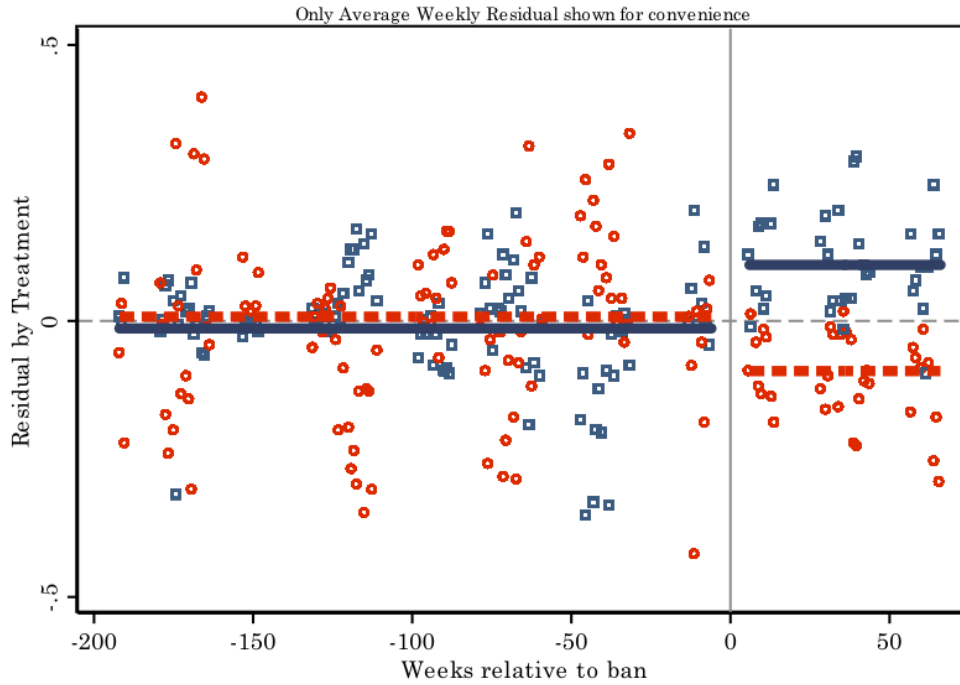


Figure 2: Scope and productivity distributions before and after the ban



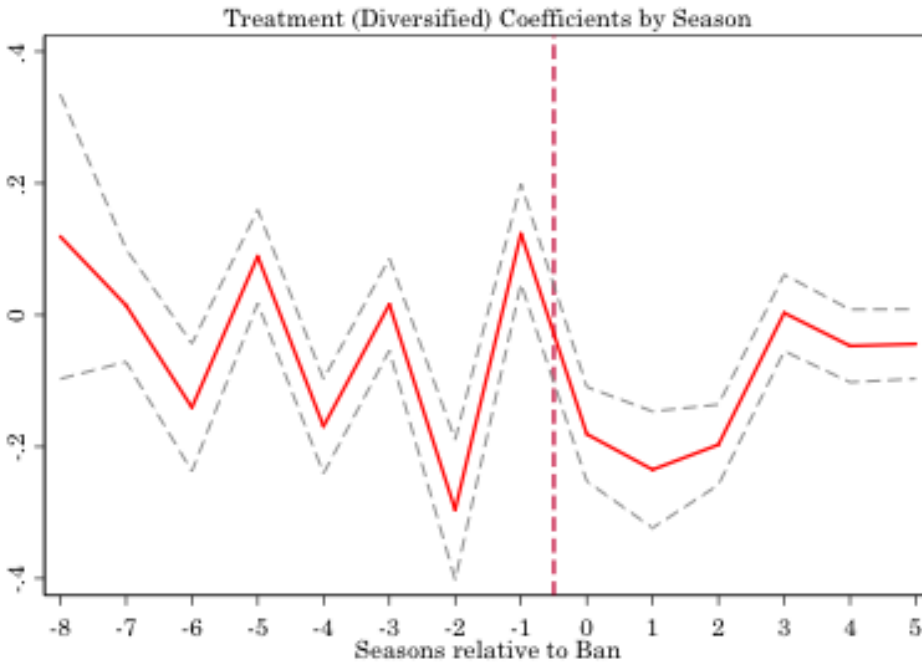
Kernel density plots of productivity distributions by firm type before and after the ban on mackerel fishing. Red dashed lines represent ships in multi-activity firms. Blue solid lines represent ships in single-activity firms.

Figure 4: Activity scope and productivity over time



Lines show average productivity for ships in single- and multi-activity firms. Points show average weekly productivity by firm type. Red circles and dashed lines show multi-activity firms. Blue squares and solid lines show single-activity firms.

Figure 5: Multi-activity firms and productivity season by season



Coefficient estimates are plotted in solid lines; confidence intervals at the 5% level are shown in dashed lines.

Table 1: Summary statistics

	<i>Correlations</i>							
	1	2	3	4	5	6	7	
<u>Ship-week level variables (n=58,107)</u>								
1	Y_{it} =tons of fish							
2	Refocus	0.06						
3	Kit=ship storage capacity	0.87	0.15					
4	Trips	0.49	0.00	0.51				
5	Multi-activity	0.41	0.38	0.48	0.08			
6	Ban	-0.13	0.65	-0.09	-0.01	-0.10		
7	Switches	0.41	0.22	0.49	0.02	0.55	-0.05	
	<i>Mean</i>	273	0.18	609	3.41	0.60	0.34	-0.07
	<i>Standard Deviation</i>	330	0.38	625	1.74	0.49	0.47	0.32
	<i>Minimum</i>	0.01	0.00	8.32	1.00	0.00	0.00	-0.29
	<i>Maximum</i>	3120	1.00	6078	7.00	1.00	1.00	7.64
	<u>Ship level variable (n=1,022)</u>							
	Ship storage capacity (m3)	<i>Mean</i>	<i>SD</i>	<i>Min</i>	<i>Max</i>			
		182.8	152.7	8.3	868.3			
	<u>Firm level variables (n=453)</u>							
	Multi-activity	0.41	0.49	0.00	1.00			
	Number of ships	2.41	4.28	1.00	61.00			

Table 2: Interdependence and productivity 1999-2003

Dependent variable = Log Y_{it} = log tons of anchovy caught by ship i in week t

Model:	OLS		D-in-D		D-in-D		D-in-D	
	(2.1)		(2.2)		(2.3)		2SLS	
							(2.4)	
Refocus	-0.21 ***		-0.20 ***		-0.16 ***		-0.24 ***	
	(0.03)		(0.03)		(0.02)		(0.03)	
Multi-activity	-0.00							
	(0.03)							
Log K_{it}	1.05 ***				1.25 ***		0.83 ***	
	(0.01)				(0.01)		(0.01)	
Log K_{it} x week f.e.	N		Y		N		N	
Firm size quintiles	Y		Y		Y		Y	
Ship fixed effects	N		Y		Y		Y	
Week fixed effects	Y		N		Y		Y	
Fish. zone fixed effects	Y		Y		Y		Y	
Adjusted R^2	0.81		0.82		0.85		n/a	
Sample size	58,328		58,328		58,328		58,328	
Number of clusters	453		453		453		886	

***, **, * = significant at the 1%, 5%, and 10% levels respectively. Robust standard errors clustered by firm (models 2.1, 2.2 and 2.3) or by ship (model 2.4) are shown in parentheses.

Table 3: Rigidity and adaptation*Dependent variable = $\text{Log } Y_{it} = \text{log tons of anchovy caught by ship } i \text{ in week } t$*

	(3.1)	(3.2)
<i>Refocus</i>	-0.07 *** (0.02)	
<i>Refocus x Season +1</i>		-0.14 *** (0.03)
<i>Refocus x Season +2</i>		-0.20 *** (0.03)
<i>Refocus x Season +3</i>		-0.16 *** (0.03)
<i>Refocus x Season +4</i>		0.04 * (0.02)
<i>Refocus x Season +5</i>		-0.01 (0.02)
<i>Refocus x Season +6</i>		-0.00 (0.03)
<i>Refocus x Season +7</i>		0.04 (0.03)
Log K_{it}	1.25 *** (0.01)	1.25 *** (0.01)
Firm size quintiles	Y	Y
Ship fixed effects	Y	Y
Week fixed effects	Y	Y
Fishing zone fixed effects	Y	Y
Adjusted R^2	0.85	0.85
Sample size	87,271	87,271
Number of clusters	453	453

***, **, * = significant at the 1%, 5%, and 10% levels, respectively.

Robust standard errors clustered by firm are shown in parentheses.

Note: the main effects of the season dummies are absorbed by the week fixed effect

Table 4: Mechanisms

<i>Dependent variable =</i>	<i>Log Y_{it}</i> (4.1)	<i>Log Trips_{it}</i> (4.2)
<i>Refocus</i>	-0.16 *** (0.02)	-0.15 *** (0.02)
<i>Refocus x Switches</i>	-0.14 *** (0.05)	
Log K _{it}	1.25 *** (0.01)	
Firm size quintiles	Y	Y
Ship fixed effects	Y	Y
Week fixed effects	Y	Y
Fishing zone fixed effects	Y	Y
Adjusted R ²	0.85	0.29
Sample size	58,328	58,328
Number of clusters	453	453

***, **, * = significant at the 1%, 5%, and 10% levels, respectively.

Robust standard errors clustered by firm are shown in parentheses.

Note: switches and the importance quartiles are time-invariant firm-level variables so their main effects are absorbed by the ship fixed effects.

Table 5: Robustness*Dependent variable = $\text{Log } Y_{it} = \text{log tons of anchovy caught by ship } i \text{ in week } t$*

Model:	No Outliers (5.1)	No VI ships (5.2)	Multi- ship firms (5.3)	Ship- specific trends (5.4)
<i>Refocus</i>	<i>-0.17</i> *** <i>(0.02)</i>	<i>-0.14</i> *** <i>(0.03)</i>	<i>-0.18</i> *** <i>(0.03)</i>	<i>-0.14</i> *** <i>(0.03)</i>
Log K_{it}	1.20 *** (0.01)	1.25 *** (0.01)	1.25 *** (0.01)	1.25 *** (0.01)
Ship-specific trend	N	N	N	Y
Firm size quintiles	Y	Y	Y	Y
Ship fixed effects	Y	Y	Y	Y
Week fixed effects	Y	Y	Y	Y
Fish. zone fixed effects	Y	Y	Y	Y
Adjusted R^2	0.87	0.84	0.85	0.85
Sample size	57,527	45,661	42,788	58,328
Number of clusters	453	420	203	453

***, **, * = significant at the 1%, 5%, and 10% levels, respectively.

Robust standard errors clustered by firm are shown in parentheses.