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This paper introduces satellite-tracked real-time data from a large fishing firm managing its vertically, horizontally, and geographically linked ships to study the causal impact of integration on total factor productivity (TFP) after the firm acquired its vertically unintegrated contractual fish suppliers. TFP increased 16% among newly integrated ships, whereas it did not vary for already owned ships. Some classic mechanisms such as increased effort due to monitoring do not systematically explain TFP gains under integration, whereas evidence on hold-up threat alleviation is mixed. Importantly, enhanced knowledge transfer and hierarchical authority enacting productivity-improving operational practices among newly integrated ships are more likely explanations of the results.

1. Introduction

The performance implications of firm boundary decisions have received enormous attention in strategy. However, three issues recently documented in the literature raise major challenges for this research. First, measuring the impact of one dimension of firm boundaries (e.g., horizontal scope) without considering other dimensions (e.g., vertical scope) may lead to incorrect conclusions about how firm boundaries impact performance (Villalonga 2004). Second, firm boundary changes are motivated by factors typically unobserved by the econometrician, thus evoking endogeneity concerns (Lafontaine and Slade 2007). Third, the "ownership" rationale for firm boundary decisions is surprisingly decoupled from the "integration" rationale, as firms in many industries only own vertical structures without actively operating their linked assets jointly (Atalay et al. 2014). As a result, whether and how integration matters for performance has become a particularly difficult question to study. This paper addresses these challenges by employing granular data on production operations and plausibly exogenous variation in firm boundaries caused by corporate acquisitions to assess the causal impact of integration on total factor productivity (TFP). The results indicate a positive, statistically significant and economically meaningful effect of integration on TFP. Moreover, the study introduces geographic information system (GIS)–based evidence

on some mechanisms linking firm boundaries, integration, and TFP.

The setting for this study, the Peruvian fishing industry, offers several attractive features to analyze the impact of integration on TFP. First, the vertical, horizontal, and geographic scope of all firms' assets can be observed in some detail. Specifically, industrial fishing consists of an upstream segment—fish extraction, the focus of this study—and a downstream segment—fish processing—with fish-procurement transactions occurring both within and across firm boundaries. Moreover, fish-extraction companies vary in the number of ships they operate and in the ocean zones they cover, thus providing rich horizontal and geographical variation to the empirical analysis. Second, proprietary access to the GIS and fish-extraction records of a large integrated firm (hereafter called the Firm) and its long-term contractual fish suppliers enables a granular analysis of integration and TFP. Because fish extraction happens on the sea in a matter of hours, satellite-tracked real-time information on how a ship relates to other ships and plants within and across firm boundaries opens a rare window onto the inner workings of operational integration. Third, asset-level ownership changes triggered by the Firm's corporate acquisitions of long-term contractual fish suppliers—events that were not directly motivated by productivity improvements—provide exogenous variation to implement difference-in-differences

models that assuage endogeneity concerns about integration and productivity. Because the ships of these long-term supplier firms were horizontally but not vertically integrated before the acquisitions, whereas the Firm's ships were both horizontally and vertically integrated, the difference-in-differences analysis exploits a sharp shift in vertical integration in conjunction with the increased horizontal scale of the formerly external fleets. Fourth, industrial fishing is a setting in which there are likely numerous factors influencing the decision to integrate over the value chain, consistent with different theories (e.g., Bolton and Whinston 1993, Kranton and Minehart 2000). The goal here is not to examine the many possible drivers of integration. Rather, the availability of exogenous variation in firm boundaries and microdata on fishing operations facilitate a theory-grounded exploration of the productivity consequences of integration.

Using the difference-in-differences approach, I find that the integration of formerly external fleets into the Firm's corporate structure leads to a 16% increase in trip-level TFP among the newly integrated ships. (A cross-sectional estimation comparing integrated and nonintegrated ships on the same day yields a 7% gain.) Specifically, taking two transactions of the same ship, both with the same plant following the same route using the same level of production factors, I find that the transaction occurring when the ship is integrated within the Firm's structure brings 16% more fish output than the one occurring when the ship is owned by a long-term contractual supplier. This result is largely insensitive to a variety of control variables and fixed effects, suggesting that integration has a positive influence on TFP that is distinct from other plausibly relevant factors. Moreover, this positive estimate using data on the Firm contrasts with a "no effect" baseline obtained using data on all trips of all ships in the industry. Although drawn from a particularly clean data segment of a broad sector, this pattern suggests that the impact of integration on TFP may not be distinguishable in cases where assortative matching, selection, and treatment forces are hard to disentangle because of sampling and endogeneity.

Besides presenting robust causal evidence on how integration increases TFP, this paper also offers exploratory evidence on why this happens. The caveat for the tests of mechanisms is that integration may impact TFP through various channels activated jointly in the setting of interest. As described above, the corporate acquisitions that brought formerly external fleets into the structure of the already vertically integrated Firm represent both a shift in the vertical status of the acquired ships and an increase in their horizontal scale. Some tests suggest that increasing horizontal fleet size does not enhance TFP in isolation from the shift in vertical status, but it is not to be concluded

that the shifted vertical status of ships with respect to plants is the only channel through which integration affects TFP. Thus, even if this exploration of mechanisms is less probative than the primary analysis, it helps assess what channels are more likely than others to explain the productivity gains of integration.

Four patterns emerge from this analysis of mechanisms. First, the productivity gain of newly integrated assets neither improves nor worsens the productivity of already integrated assets (see Schoar 2002 and Mingo 2013 for contrasting evidence on legacy assets' performance after acquisitions). Second, I find that some classic roles of integration in solving contractual frictions such as low upstream effort resulting from little monitoring do not systematically relate to TFP gains, though evidence on the existence of hold-up threats by downstream plants alleviated by integration is mixed. Third, I find that newly integrated assets implement a number of more focused operational and deployment practices (e.g., shorter distance to neighboring ships, more persistence in fishing areas, less meandering on return trips) that correlate well with higher productivity. Moreover, I find that the Firm's already owned ships start interacting more closely with the newly acquired ships, suggesting a lateral transfer of knowledge about these practices. Fourth, I show that these operational practices are not uniformly adopted by all newly integrated ships, suggesting a temporary compromise of a few units for the benefit of the overall organization. Some of the formerly unintegrated ships or their captains are not well suited for more productive operations. Furthermore, some operational practices are implemented quickly, while others take longer. The productivity-enhancing practices are not fully adopted by external fleets before integration with the Firm, suggesting an unwillingness or inability to enact these policies outside the authority realm of a common hierarchical organization structure.

Taken together, the evidence is consistent with a TFP gain through knowledge sharing in an integrated structure. The findings indicate that not all operational changes under integration enhance productivity; moreover, the average gain is assessed here in the broader context of a full distribution of gains in which not all units improve after integration.

This study offers a strategy perspective on how and why integration matters for firm performance. First, the study advances the influence of integration on *total factor productivity*, thus connecting a theory-grounded within-firm production function framework (Syverson 2011) with the broad agenda on firm scope and performance in strategy (e.g., Poppo and Zenger 1998, Macher 2006, Novak and Stern 2008) and organizational economics (e.g., Forbes and

Lederman 2010). Second, the study provides a general insight into the hard and soft forces shaping integrated operations. This tension is central in recent work on the causes and consequences of firm ownership boundaries. On one hand, Hortaçsu and Syverson (2007), Ramondo et al. (2013), and Atalay et al. (2014) conjecture that firms own units in different segments of the value chain not necessarily to benefit from their integrated production but to profit from their related knowledge and intangibles (unobserved by the econometrician). On the other hand, Pérez-González (2005) finds that capital investment is a tangible mechanism linking ownership and TFP. This study suggests that, in the case of fishing, the connection between ownership and productivity happens through integration but is less based on physical investment mechanisms (Grossman and Hart 1986) and possibly more knowledge-based and interpersonal (Garicano and Rossi-Hansberg 2006, Van den Steen 2010). Although the mechanisms I propose can only remain exploratory here, the magnitude of the main effect warrants renewed attention in the literature going forward (Gibbons 2010, Syverson 2011).

This paper also introduces *geographic information systems* to strategy. Empirical work exploiting GIS is rapidly moving from specialized areas to the mainstream (e.g., Dell 2010, Burgess et al. 2012), but much of this research has so far focused on cross-sectional or low-frequency settings. My study of real-time fishing offers something new by advancing the microcosm of firm boundaries as an area of broad scholarly and practical interest in which GIS may help address fundamental questions in strategy.

This paper is organized around testing a causal relationship first and next exploring its underlying mechanisms (see Kellogg 2011 for a related example). Section 2 introduces the Peruvian fishing industry and §3 clarifies the importance of relating integration to total factor productivity using data on the Firm and its suppliers. Section 4 describes the data. Section 5 details the empirical design. Section 6 presents the main results and §7 reports tests of mechanisms. Section 8 concludes.

2. Institutional Background

2.1. Industrial Fishing
My analysis of integration and productivity builds on an economic tradition that studies the contracting environment of fisheries (e.g., Johnson and Libecap 1982, Koss 1999, Jensen 2007). Industrial fishing consists of the capture of wild fish by large-scale vessels operated by professional crews. In the Peruvian fishery, the setting for this study, ships are technologically capable of extracting fish, not transforming it. Extraction companies capture fish from the Pacific

Ocean, bring them to the coast, and sell or transfer them to processing plants. By contrast, processing companies acquire or source raw fish to transform them into fishmeal (a flour-like paste used as an animal feed) or seafood at their plants.

Fish populations are both mobile and imperfectly observable—wild fish are alive and instinctively avoid getting captured. There are no territorial partitions of fishing grounds—by law, any extraction company with a license can operate anywhere on the ocean.[1] Even if ships may freely search the whole Peruvian sea area for fish, the combinatorial complexity of planning routes on a large surface is high. Thus, the search choices of a given ship are conditioned by the different natural likelihoods of fish abundance across latitudes, the deployment decisions of other ships, and the fixed locations of plants. As will be shown in detail in the empirical design, these geographic considerations play a key role in how firm boundaries influence ship productivity, the central construct of interest here.

2.2. Firm Boundary Decisions of Fish-Extraction Companies
A first dimension in which fish-extraction companies vary is their horizontal scale. Specifically, although a single industrial ship is self-sufficient to conduct extraction operations, companies may choose to operate multiship fleets. Because regulation caps the extraction capacity of each ship and the entry of new ships, the horizontal scale of fleets typically varies through ownership changes following mergers and acquisitions. Although different firms may have different rationales to choose their fleet size, the motivations include economies of scale and scope arising from risk management and shared efficiencies in the process of finding and extracting fish.

A second scope decision of extraction companies is whether they should only operate in the (upstream) fish-extraction segment of the industry or whether they should also concurrently operate in the (downstream) fish-processing segment through affiliation with plants. Both vertically integrated and unintegrated extraction companies can coexist in equilibrium for at least two reasons. First, fish extraction is subject to stochastic natural shocks that make different plant locations unequally attractive destinations at a given moment. Consistent with theories of integration (e.g., Bolton and Whinston 1993, Kranton and Minehart 2000), these spatial and temporal shocks can

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[1] Although I cannot demonstrate that all ships always have access to all fishing grounds, a simple inspection of landing data for the population of trips in the industry suggests that ship locations are sufficiently dispersed to assuage concerns of unlawful foreclosure among ships.

be more effectively smoothed out by networks of vertically unintegrated fleets selling fish to third parties than by possibly less flexible vertically integrated fleets. Second, government regulations prohibit vertical integration in some cases (i.e., wooden ships[2]), and the investment required to acquire a processing plant is beyond the reach of some extraction companies. Hence, it is not uncommon that some firms find it optimal to remain independent from plants, developing informal supply relationships.

The analysis of the productivity implications of integration over the value chain raises the question of whether similar outcomes could be achieved through contracts instead of ownership. Anecdotal evidence suggests that fishermen can raise a number of objections to downstream requests, analogous to the conflicts in trucking between drivers and carriers (Baker and Hubbard 2004). Importantly, fishermen's hold-up risk with respect to ship owners is assuaged by the "lay system" of pay, according to which ship captains and workers are compensated exclusively in direct proportion to output, regardless of the total fish captured both in integrated and unintegrated firms (Johnson and Libecap 1982, McConnell and Price 2006).[3] However, it is still possible that contractual frictions caused by incentive misalignment across firm boundaries persist, as will be analyzed in §7. Other operational frictions further examined in §7 include the sensitive nature of intangibles (e.g., knowledge of extraction practices) not optimally communicated without integration (e.g., Macher 2006).

2.3. Patterns of Firm Boundaries and Productivity Across the Industry

Before introducing the main empirical design, I first describe the scope configuration and output patterns of all extraction companies in the industry in a regression framework. To do this, I employ data on all fishing operations between January 1, 2003, and July 31, 2008, the period for which industry extraction data are complete. Inspecting broad patterns across the industry is useful to understand the nature of the economic environment, as well as the potential challenges for causal inference to be addressed.

Panel I of Table 1 details the sample for this descriptive analysis. The information on 380,982 trips includes ship identity and vertical and horizontal ownership status, the location of each destination port, the output in tons of fish caught, and ship hold capacity in cubic meters.

To describe the relationship between fish output (i.e., weight of fish caught) and ownership status in the case of ship j during trip i ending on date t, I employ

$$y_{ijt} = \beta_0 + \beta_1 * VS_{jt} + \beta_2 * HS_{jt} + \beta_3 * k_j + \beta_4 * X_{ijt} + \delta_j$$
$$+ \tau_{y \cdot \text{week}(t)} + \eta_g + \mu_{ijt}, \qquad (1)$$

where y_{ijt} is the logarithm of output; VS_{jt} is a dummy for whether the ship is vertically linked through ownership with a downstream plant; HS_{jt} is a dummy for whether the ship is horizontally linked through ownership with another ship; k_j is the logarithm of the capital equipment of a ship, that is, its hold capacity in cubic meters; X_{ijt} is a vector of control variables; δ_j is a ship fixed effect; $\tau_{y \cdot \text{week}}$ is a year-week fixed effect; η_g is a port-of-destination fixed effect; and μ_{ijt} is an error term. Note that the coefficient β_3 on logged capital cannot be separately identified from the ship fixed effect, as ship capacity k_j is time-invariant by regulation in the industry.

Table 2 presents regression results based on Equation (1). These fixed effects models suggest that neither the horizontal ownership status of a ship nor its vertical ownership status is significantly correlated with output when estimated separately in the first two columns of Table 2. These dimensions also appear insignificant when entering jointly the regression in the third column.

A first reading of Table 2 would appear to suggest that a firm's vertical or horizontal scope is not positively correlated with productivity across the industry. However, there can be different interpretations of these null results. Different market equilibrium forces may counteract one another, thus making the coefficients appear insignificant in equilibrium. It is also possible that assets owned by a firm across different links of the value chain are not really operationally integrated (e.g., Atalay et al. 2014). Last, the endogeneity of integration choices and measurement error in TFP may hamper causal inference in specification (1).[4] These identification issues are the point of departure for my empirical investigation of how integration impacts TFP.

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[2] All ships of the Firm and its long-term supplier firms studied here are steel ships.

[3] An untabulated analysis of workers' pay, available only for the Firm's ships, indicates that the lay system is in place.

[4] To further probe how this industry data set could help distinguish vertical or horizontal ownership in relation to fish output, I conducted a test of matched pairs of ships in which one ship is vertically linked to plants and the other is not, both ships being otherwise very similar in their initial conditions. After horizontal acquisitions conducted by companies that owned these matched pairs of ships increased horizontal scale, I found no significant impact of horizontal scale on productivity. Hereafter, I only employ data on the Firm, its suppliers, and comparable companies in the analysis.

Table 1   Summary Statistics

	Mean	Median	Std. dev.	Min	Max
Panel I. Industry trip-level population ($n = 380{,}982$)					
Vertical ship	0.26	0.00		0.00	1.00
Output	89.21	51.89	97.10	0.01	810.05
Capital	187.12	128.00	151.99	2.78	868.27
Panel II. The Firm's trip-level sample ($n = 13{,}536$)					
Integrated ship	0.51	1.00		0.00	1.00
Output	203.45	177.60	150.24	0.05	624.97
Capital	367.52	365.00	163.96	72.84	614.05
Labor	15.39	16.00	2.61	9.00	18.00
Use	32.61	23.21	28.28	2.00	397.00
Distance	304.04	197.01	352.12	8.12	2,528.65
Mean speed	8.57	8.18	3.52	0.31	32.76
Standard deviation of speed	6.24	6.22	2.45	0.00	46.94
Neighbor separation	33.98	9.45	82.86	0.02	1,433.01
Firm neighbor separation	91.80	40.27	150.73	0.00	1,444.59
Number of tries	15.19	11.00	18.20	0.00	451.00
Distance to prior fishing area	107.72	47.72	173.20	0.00	1,413.19
Meander ratio	1.86	1.16	2.17	1.00	72.42
Sale to third parties	0.07	0.00	0.25	0.00	1.00
Fuel price	2.37	2.42	0.36	0.48	3.16
Ban on anchovy	0.22	0.00		0.00	1.00
Ban on white anchovy	0.19	0.00		0.00	1.00
Announced ban on anchovy	0.09	0.00		0.00	1.00
Announced ban on white anchovy	0.08	0.00		0.00	1.00
Fishing for fishmeal	0.56	1.00		0.00	1.00

	Count
Panel III. The Firm's sample	
Total number of ships	$50 < N < 100$
Always owned, no long-term contract	$\approx 0.37N$
First long-term contract, then owned	$\approx 0.60N$
Always long-term contract	$< 0.03N$

Notes. This table defines trip-level variables on the population of ships in the industry for the period from January 1, 2003, to July 31, 2008 (panel I), trip-level variables on ships owned and contracted through long-term agreements by the Firm for the period from January 1, 2003, to April 15, 2010 (panel II), and information on the Firm's ships with exact details suppressed for confidentiality (panel III). *Vertical ship* is a dummy for whether the ship is owned by a firm that also owns fish processing plants; in the case of panel II, this variable is labeled *Integrated ship*, and the only firm with plants is the Firm. *Output* is in tons (000 of kilos) of fish caught on the trip. *Capital* is the ship's hold capacity in cubic meters. *Labor* is the number of crew members on the ship. *Use* is the duration of the trip in hours. *Distance* is the exact geographical movement of the ship throughout its trajectory as measured by the satellite. *Mean speed* is distance divided by use. The *standard deviation of speed* on a given trip uses the speed between consecutive locations measured by the satellite to calculate the trip-level standard deviation of speed. *Neighbor separation* is the average distance to the nearest ship calculated at each point of the trajectory of the ship with respect to any ship of the Firm or its long-term contractual suppliers. *Firm neighbor separation* is an analogous measure but calculated only with respect to the Firm's owned ships. *Number of tries* is the number of times the ship is detected to be moving at less than 2.9 kilometers per hour, proxying for an attempt to fish. *Distance to prior fishing area* is the distance of the current trip's maximum point off the coast and the same ship's maximum point off the coast on the immediately preceding trip, in kilometers. *Meander ratio* is the distance travelled by the ship between its maximum point off the coast and its destination plant divided by the straight line between those two points. *Sale to third parties* is a dummy for whether the ship sells its catch to a firm other than the Firm. *Fuel price* is a daily series of price per gallon of diesel expressed in dollars after national taxes. *Ban on anchovy* (*ban on white anchovy*) is a dummy for whether there is a ban on fishing that species for fishmeal that day at the location of landing. *Announced ban on anchovy* (*announced ban on white anchovy*) is a dummy for the days between a government's announcement of a ban and the day of enactment of the ban. *Fishing for fishmeal* is a dummy equal to 1 when the purpose of the trip is to catch fish for fishmeal and 0 when the purpose is to catch fish for seafood; by regulation, the purpose of a trip is always determined in advance, so it is not contingent on within-trip decisions.

3. Integration and Total Factor Productivity

This is one of the first studies that causally links integration and TFP, two constructs that have received much attention separately but not jointly. Regarding the first construct, integration is viewed here as a firm's choice of whether to jointly operate productive assets within firm boundaries instead of solely transacting on the market. As described in §2, industrial fishing offers substantial variation in the dimensions requiring integration, a feature that will be exploited in the empirical analysis.

Regarding the second construct of interest, TFP, the data employed here allow for more precise measurement than in prior work that has typically required extra assumptions to offer insight into TFP. As noted

Table 2   Firm Boundaries and Trip Productivity Across the Industry

Dependent variable:	Log(*Output*)		
	(2.1)	(2.2)	(2.3)
Vertical ship	−0.021		−0.018
	(0.02)		(0.02)
Horizontal ship		−0.012	−0.007
		(0.02)	(0.02)
Fuel price	−0.160	−0.161	−0.160
	(0.14)	(0.14)	(0.14)
Ban on anchovy	−0.060***	−0.060***	−0.060***
	(0.01)	(0.01)	(0.01)
Ban on white anchovy	−0.016	−0.016	−0.015
	(0.02)	(0.02)	(0.02)
Announced ban on anchovy	−0.096***	−0.096***	−0.096***
	(0.01)	(0.01)	(0.01)
Announced ban on white anchovy	0.097***	0.097***	0.097***
	(0.01)	(0.01)	(0.01)
Fishing for fishmeal	0.809***	0.809***	0.809***
	(0.07)	(0.07)	(0.07)
Fixed effects:			
Ship	Yes	Yes	Yes
Year–week	Yes	Yes	Yes
Arrival port	Yes	Yes	Yes
R^2	0.71	0.71	0.71
Sample size	380,982	380,982	380,982
Number of clusters (ships)	1,643	1,643	1,643

Notes. This table describes the relationship between each ship's scope configuration and output across the industry. The unit of observation is a fishing trip, and the sample is all trips of all ships of the industry. *Horizontal ship* is a dummy equal to 1 when the ship is affiliated through ownership with at least one other ship in a given month. All other variables are defined in Table 1. Robust clustered standard errors are reported in parentheses.

***Significant at the 1% level.

by Syverson (2011) in his review of new developments in productivity research, very little is known about how TFP depends on firm scope configurations in isolation from other factors.

It is advantageous to exploit granular data on integration and TFP to approach the question of interest, but refined measurement is not sufficient to address concerns about the endogeneity of scope decisions (Lafontaine and Slade 2007). Specifically, the match of integration processes and foreseeable outcomes is typically not random. For example, successful firms tend to own production chains, a scope decision that may correlate well with higher TFP and success (Atalay et al. 2014). I therefore exploit exogenous variation provided by corporate events surrounding a single firm to assess the causal impact of integration on productivity, as described next.

3.1.   "Insider Econometrics" Using Proprietary Data on a Firm and Its Suppliers
My main analysis employs granular data on a single vertically, horizontally, and geographically integrated fishing firm in connection with its long-term suppliers

of fish. I focus exclusively on the (upstream) extraction segment's productivity in the analysis of how integration impacts productivity.

The Firm processes fish from four sources: first, its own ships; second, its long-term contractual supplier firms, with whom it fully shares operating information and from whom it enjoys a special priority—with no obligation or guarantee to buy or sell on either part—to receive fish catches; third, weak-relationship suppliers without shared information; and fourth, spot transactions. Although the total number of ships providing the Firm with fish surpasses 1,000, the main sample consists of the first two groups, accounting for 53% of the Firm's fish before the latest corporate acquisitions and totaling between 50 and 100 ships, with the exact number omitted for confidentiality.[5]

The Firm, as other integrated processors in the industry, maintained several formal and informal relationships with fish suppliers, choosing not to write trip-by-trip contracts, possibly because of the unobservability of catches in real time and the relatively underdeveloped judicial system of the country.[6] Instead, unwritten nonbinding agreements (called long-term contracts in this paper for simplicity) were in place. Interestingly, plants did not pay markedly higher prices to ships with stronger contractual strength. The long-term contractual suppliers of interest were vertically unintegrated companies, each with multiship fleets that did not have long-term agreements with other processing firms. These suppliers generally complied with providing a large share of their catch to the Firm.

Although information on the relations of the Firm with its weaker link and spot is not granular enough to provide a full characterization here, qualitative evidence suggests that the Firm preferred to source fish first from its own ships, next from its long-term contractual suppliers' ships, and only after these, from weaker-link and spot suppliers' ships.

3.2.   Advantages and Limitations of the Setting to Analyze Integration
Focusing the analysis on the Firm and its long-term contractual suppliers offers some clear advantages for assessing the impact of integration on productivity. First, TFP can be measured with granular precision for both owned and external ships. Second, the Firm pursued corporate acquisitions whereby it acquired

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[5] Supplemental evidence on changes in the whole set of fish procurement transactions of the Firm is discussed in §7.4.

[6] According to the World Bank's Development Indicators, the procedures to enforce a contract in Peru are more numerous (i.e., more costly) than in the other two largest fishing countries, China and Chile.

the entire multiship fleets of its long-term contractual suppliers; as will be explained in §5.2, the reasons leading to these acquisitions were not directly related to productivity enhancements, thus providing plausible exogenous variation in the integration status of external fleets. Third, GIS records on the Firm's own ships and the ships of its long-term contractual suppliers both before and after integration facilitate the exploration of mechanisms behind TFP changes. Finally, a long-standing relationship between the researcher and the Firm facilitated the fieldwork supplementing the analysis.

While the setting offers empirical advantages, it also presents limitations. First, the corporate acquisitions conducted by the Firm implied a dual integration change for formerly external fleets: a shift in vertical integration and an increase in horizontal scale. Although some tests described below may appear to more intuitively support one dimension of integration than the other, the main purpose of this study is to assess the overall causal impact of integration and explore its mechanisms. Second, the inherent characteristics of the Firm and its long-term suppliers may differ from the average industry participants because of sampling, so the average treatment effects obtained here may not generalize to other firms. These boundary conditions are directly invoked when presenting the results.

4. Data

A contribution of this paper is to introduce GIS measurement to the study of integration and total factor productivity. Per the General Fishing Bill of Peru,[7] a system of satellite surveillance is mandated for all firms in the industry, with the goal of overseeing good fishing practices and controlling the extraction of fish, a national good. The specific regulation for the satellite system[8] details that the functioning of the transmission equipment on board is mandatory for all industrial ships and for all periods, regardless of whether ships are fishing. The information, transmitted in real time, includes date and time, ship ID, longitude and latitude (with a precision of ±100 meters), speed, and direction. The providers of the satellite system are private firms authorized by the government.

The GIS records on the Firm's own fleet and the fleets of its long-term suppliers before and after integration are available for the period between January 1, 2003, and April 20, 2010. This information becomes richer when combined with the hourly records on the Firm's plants (through 2010) and with

daily records on all ships and plants in the industry (through 2008). In the case of the Firm, I employ simple algorithms to link GIS measures and economic outcomes, resulting in a total of 13,536 trips with 689,084 satellite snapshots, an average of 51 snapshots per trip. Distances between two points in the trajectory of a ship, or between the ship and a plant, are calculated using the Haversine formula,[9] which accounts for the curvature of the Earth. Table 1 defines the main variables of the study and provides summary statistics on the Firm's own ships and those of its long-term contractual suppliers.

5. Empirical Design

To model the impact of integration on TFP at the level of each fishing trip, I first start with a standard multiplicative production function that is further extended to consider integration. Then I detail the identification strategy.

5.1. Specification

As defined in §4, the sample is exclusively formed by ships of the Firm and of its long-term contractual suppliers. Because all these firms remain horizontally integrated throughout the study, the definition of integration employed hereafter refers to a ship-specific time-varying dummy that gets shifted from zero to one for the newly acquired ships at the moment of the acquisition events; the horizontal scale of a ship's fleet is introduced as an additional explanatory variable, as well.

For the case of ship j during trip i ending on date t, consider the multiplicative form

$$Y_{ijt} = L_{ijt}^{\alpha} * K_{ijt}^{\rho} * M_{ijt}^{\gamma} * X_{ijt}^{\theta} * \epsilon_{ijt}, \quad (2)$$

where K_{ijt} is the use of capital during the trip, L_{ijt} is the use of labor, M_{ijt} is the use of fuel and other materials, X_{ijt} are control variables, and ϵ_{ijt} is an error. All variables are in physical quantities, thus providing some methodological advantages over revenue-based measures (Foster et al. 2008). A key feature of fishing trips is that the use of capital, labor, and inputs can be parameterized as a direct function of the duration of the trip, labeled here as U_{ijt}, thus becoming

$$Y_{ijt} = (L_j * U_{ijt})^{\alpha} * (K_j * U_{ijt})^{\rho} * (M_j * U_{ijt})^{\gamma} * X_{ijt}^{\theta} * \epsilon_{ijt}, \quad (3)$$

$$= U_{ijt}^{\phi} * (L_j)^{\alpha} * (K_j)^{\rho} * (M_j)^{\gamma} * X_{ijt}^{\theta} * \epsilon_{ijt}. \quad (4)$$

Transforming (4) by taking logarithms leaves the general productivity specification

$$y_{ijt} = \phi * u_{ijt} + \alpha * l_j + \rho * k_j + \gamma * m_j + \theta * x_{ijt} + \nu_{ijt}, \quad (5)$$

[7] Decreto Supremo 012-2001-PE of March 13, 2001.
[8] Decreto Supremo 026-2003-PRODUCE of September 12, 2003.

[9] Available at http://www.movable-type.co.uk/scripts/latlong.html, last accessed October 26, 2012.

and by extension, the impact of integration on total factor productivity can be expressed as

$$y_{ijt} = \beta * IS_{jt} + \phi * u_{ijt} + \alpha * l_j + \rho * k_j + \gamma * m_j + \theta * x_{ijt} + \nu_{ijt}, \quad (6)$$

where *Integrated ship* (IS_{jt}) is the time-varying explanatory variable of interest. The use of inputs u_{ijt} is observed with precision through satellite tracking (e.g., Mullowney and Dawe 2009) and introduced in the specification, thus avoiding an incorrect inference about productivity gains when inputs cannot be observed. Even if this cross-sectional specification narrowly compares integrated assets with third-party ships, the preferred specification improves upon (6) to estimate

$$y_{ijt} = \beta * IS_{jt} + \phi * u_{ijt} + \theta * x_{ijt} + \delta_j + \tau_{y \cdot \text{week}(t)} + \kappa_{(rw) \times j} + \zeta_{(rw)^2 \times j} + \lambda_{\text{route}} + \nu_{ijt}, \quad (7)$$

where δ_j is a ship fixed effect that subsumes the ship-fixed factors l_j, k_j, and m_j; linear and quadratic relative week trends κ_{rw} and $\zeta_{(rw)^2}$ with respect to the date in which each asset becomes integrated, or zero otherwise, are interacted with ship fixed effects; and λ is a route fixed effect. The first advantage of specification (7) consists in capturing asset-level time-invariant heterogeneity. A second benefit of Equation (7) is the inclusion of route fixed effects λ for these fishing trips, defined as joint fixed effects for the triad (*plant of departure, plant nearest the zone of fishing, plant of arrival*) that capture variation originating in how ships move to latitudes[10] that may be more productive. Third, including linear and quadratic trends interacted with ship fixed effects assuages concerns about other shifters moving simultaneously with integration. Standard errors are conservatively clustered at the level of each ship. The identification assumptions to interpret β are provided in §5.2.

The inclusion of exogenous control variables strengthens specification (7). Fuel prices capture exogenous cost shocks. Bans on anchovy or white anchovy are dummies reflecting whether the government imposed a ban on fishing these species for fishmeal at that port on that day, thus controlling for potential changes in ship behavior. Announced bans on anchovy or white anchovy are dummies for the period between the announcement of bans and the beginning of their enforcement, thus controlling for fishing intensity. In addition, fishing for fishmeal is a dummy controlling for differences across fishing

purposes; by regulation, this variable becomes fixed when the trip starts.

Specification (7) is preferred for its granularity and consistency within a production function framework, yet the empirical design also includes other trip-level models as well as a more aggregate analysis of the consequences of integration that can help assess the mechanisms behind the main effect.

5.2. Identification
Identification is facilitated by the observation of changes in ownership brought about by corporate acquisition events. Specifically, at different points in time the Firm decided to more fully integrate backward, acquiring the fleets of long-term suppliers of fish. To illustrate, consider two ships supplying fish to the Firm's plants. One of the ships is owned by a long-term supplier and the other is owned by the Firm. At some point, the supplier ship's operator learns that its owner has changed, becoming the Firm. Under the null that the operation and productivity of the ships are random, the ship operators do not care, so the acquisition will have no effect on operations or productivity. However, if integration into the Firm affects the way ships behave, integration will lead to operational changes among formerly external ships and will possibly influence their performance. Because integration status shifts only for formerly external ships and leaves already owned ships unchanged, a difference-in-differences test would remove biases because of omitted variables or endogeneity concerns.

This empirical design requires that long-term contractual suppliers be acquired for reasons somewhat unrelated both to the way ships operate on the sea and to anticipated reasons for changing fishing behavior after acquisition. Understanding the drivers of these acquisitions is important because, if there are unobservables that are correlated with the Firm's decision to acquire its long-term suppliers and also with the operations and performance of the acquired ships, the tests would be problematic. There is no need to assume that the acquisitions were randomly determined. Rather, I need to inquire whether acquisition-related unobservables are mechanically determining productivity.

The Firm embarked on two sets of corporate acquisitions, each set being conducted at different moments in the period 2003–2010 and referred to here as "early" and "late," with some details suppressed for confidentiality. All acquisitions involved the block purchase of ships of long-term contractual suppliers (i.e., no selection of good ships versus bad ships was conducted); only one long-term supplier firm with very few ships was never purchased. The early acquisition was of a long-term supplier company with only

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[10] The Peruvian coastline runs roughly from north to south; thus, the plants used for these fixed effects mostly capture north-south movements in various directions.

two monospecies (nonanchovy) ships at a point of the industry life cycle when the species on which these ships depended was at its lowest captured volume in years. In the late set of acquisitions—several years apart from the early one—the Firm acquired its two largest long-term suppliers. This late set of acquisitions increased the Firm's fleet significantly with multispecies ships; only one of the ships of one of the companies acquired was monospecies. The years-long lag between the early and late acquisitions and the stark contrast in the types of ships involved suggest that learning-about-acquiring effects accruing between the moments of the early and late acquisitions are small or nonexistent and do not jeopardize the empirical design.

Qualitative evidence suggests that operational improvements were not anticipated by those conducting the acquisition deals. Regarding the early acquisition, an industry analysis of its nearly disappeared fishery suggests that the Firm acquired a long-term supplier with relatively dim prospects of future profitability. The late acquisitions, however, require further inspection, as they involved large suppliers with very active fleets. First, interviews with shareholders and managers of the Firm indicate that the conditions leading to these acquisitions included the need for a larger corporate size to face the competitive environment, the need for a larger balance sheet to raise more bank financing, and a largely exogenous request of more collateral from a bank syndicate as the basis for more sophisticated financing operations in the future. Because none of these aspects is linked to differential behavior of newly acquired versus already owned ships, the assumption of uncorrelated unobservables seems plausible.

Second, interviews with external participants in these acquisition decisions—the law firm and the investment bank advising the Firm—further validate this anecdotal evidence. When asked whether changes in fishing behavior and productivity were foreseen at the moment of negotiations, the principals of these advising firms suggested that this was not the case. Again, the stated reason behind the acquisitions was financial rather than operational.

There exist two other advantages that further strengthen the use of corporate acquisitions as a valid shifter in external ships' integration. First, the biological factors that affect trip productivity are largely random, and therefore, even if unobservable, they are unlikely to be correlated with changes in the integration status of a given ship. Second, anecdotal evidence from fieldwork suggests that after integration, several potentially important shifters of performance remained fixed. For example, no systematic changes in ship crew composition, the lay system of pay, relation-specific investments, or technology were

implemented. I explore some of the channels linking integration and total factor productivity in §7, after presenting the main results.

6. Main Results

Panel A of Figure 1 presents a difference-in-differences plot of the output of catches before and after the integration events. The overall pattern suggests that integration leads to a substantial increase in output among formerly contractual ships, leaving already integrated ships relatively unaffected. However, the graph also shows much variation that must be addressed in the regression analysis.

Table 3 presents the main regression results. The sample for these tests include trips of the Firm's ships and its long-term contractual firms' ships. The first model estimates Equation (6), that is, a cross-sectional specification that does not include ship fixed effects or year-week dummies. Instead, to make the comparison across ships meaningful, interaction fixed effects based on the triad (*date of arrival, departure port, arrival port*) are employed, as well as hour-of-departure dummies. The results suggest that seemingly identical transactions are more productive for integrated ships than for external ships in the cross-section, with a 7% differential accruing to ship integration. As expected, the coefficients on capital, labor, and use are positive and significant.

The second column of Table 3 estimates Equation (7), a ship fixed effects model. The coefficient on integration is statistically significant and larger than in the cross-sectional estimation, indicating a gain of 14.4% for formerly external contractual ships. As detailed in §5.1, production inputs are uniquely captured by the duration of the trip, tracked by the satellite system. This specification also allows for the introduction of exogenous controls that vary for each day and each week.

The results obtained so far may be subject to the criticism that other shifters of productivity vary at the same time as ship integration. The inclusion of linear and quadratic trends in specification (7), however, assuages these concerns. The third model of Table 3 estimates (7) introducing linear and quadratic ship-specific trends relative to the moment in which assets became integrated into the Firm, or zero if they never changed their integration status. The coefficient on integration remains positive and economically significant, indicating a 17.3% TFP gain attributable to the fact that the ship is integrated with the ships and plants of the Firm.

Although the difference-in-differences design focuses on changes happening to long-term suppliers after integration, the Firm also obtains fish from its own ships. It might be argued that the positive

Figure 1   Output and Productivity by Treatment Before and After Integration

Panel A: Weight of output

Panel B: Kernel densities of trip TFP
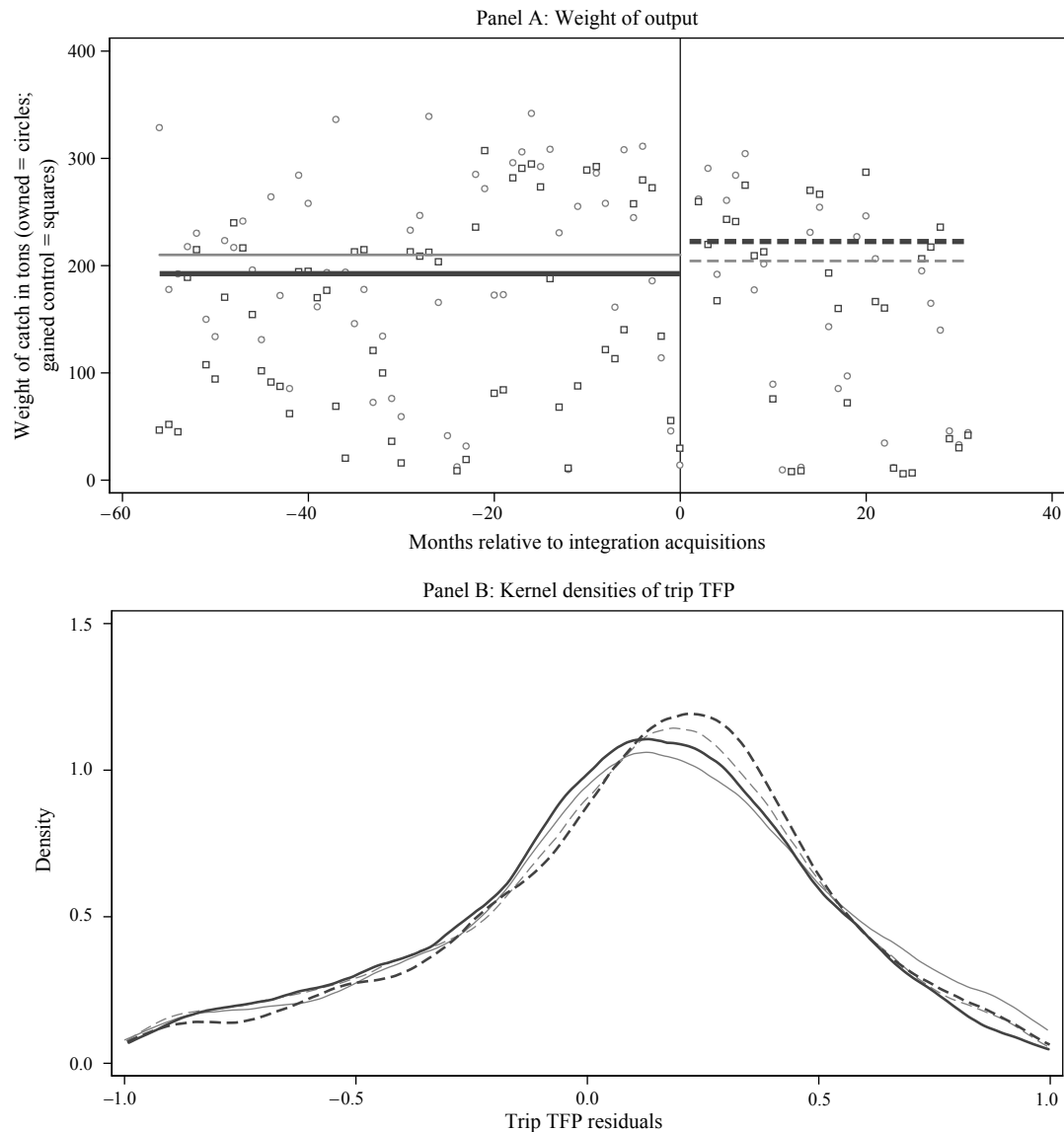
Notes. This figure shows output data (panel A) and productivity residuals (panel B) on owned and contractual ships before and after integration into the Firm. Panel A summarizes the weight of catches at the monthly level for all trips of owned ships (circles) and long-term supplier ships that become integrated after being acquired by the Firm (squares). The pre- and postintegration sample averages of the raw monthly data are displayed by a thick line for ships that become integrated and a thin line for ships that are always owned. Panel B displays the kernel densities of residuals of a full trip-level productivity regression (Model 3.4), grouping the observations into four juxtaposed curves: owned by the Firm before integration of long-term contractual suppliers (thin solid line), owned after integration (thin dashed line), long-term contractual ships before they become integrated (thick solid line), and long-term contractual ships after they become integrated (thick dashed line). The four kernel density curves are shown only for the range [−1, 1] for ease of reading.

effect of integration on TFP among formerly long-term contractual ships happens simultaneously with other sourcing policies of the Firm. For example, the Firm could have started using its existing ships less often than before the acquisition events, thus displacing its ships from the ocean to give preference to the newly integrated firms. Moreover, the Firm might have changed its sourcing strategies with respect to other third-party ships.

To address these arguments empirically, the fourth model of Table 3 includes additional explanatory

variables capturing the microdynamics of competition and procurement. First, the number of ships in the fleet to which the ship in question belongs helps address the displacement story whereby productivity would increase for newly integrated ships. It is important to note that this variable also captures the horizontal scale of the ship's fleet, which may change from week to week and, more substantially, from before integration to after integration for both formerly external and already internal ships. This variable shows a positive and significant coefficient,

Table 3 Integration and Trip Total Factor Productivity

Dependent variable:	Log(*Output*)					
Sample periods:	All	All	All	All	As in Table 2	
	(3.1)	(3.2)	(3.3)	(3.4)	(3.5)	(3.6)
Integrated ship	0.070**	0.144***	0.173***	0.161***	0.125**	0.202**
	(0.03)	(0.05)	(0.06)	(0.05)	(0.06)	(0.08)
Log(*Capital*)	0.861***					
	(0.04)					
Log(*Labor*)	0.569***					
	(0.18)					
Log(*Use*)	0.060**	−0.008	−0.008	−0.006		0.026
	(0.03)	(0.02)	(0.02)	(0.02)		(0.02)
Fuel price		−0.234	−0.254	−0.280	−0.378	−0.416
		(0.34)	(0.33)	(0.33)	(0.26)	(0.25)
Ban on anchovy		−0.102**	−0.107**	−0.102**	−0.109**	−0.089
		(0.04)	(0.04)	(0.05)	(0.05)	(0.06)
Ban on white anchovy		0.001	0.007	0.000	0.073	0.039
		(0.06)	(0.06)	(0.06)	(0.06)	(0.07)
Announced ban on anchovy		0.043	0.034	0.037	0.043	0.044
		(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Announced ban on white anchovy		−0.031	−0.027	−0.029	−0.015	−0.019
		(0.06)	(0.07)	(0.07)	(0.07)	(0.07)
Fishing for fishmeal	0.023	0.004	0.008	0.007	−0.021	−0.015
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Number of ships in fleet fishing this week				0.031***		0.036***
				(0.01)		(0.01)
Number of third-party ships at this port, this week				−0.001**		−0.001
				(0.00)		(0.00)
Number of third-party infractions in this area, this week				0.000		0.000
				(0.00)		(0.00)
Fixed effects:						
Ship	No	Yes	Yes	Yes	Yes	Yes
Year–week	No	Yes	Yes	Yes	Yes	Yes
Date × departure port × arrival port	Yes	No	No	No	No	No
Hour of departure dummies	Yes	No	No	No	No	No
Departure port × fishing port × arrival port	No	Yes	Yes	Yes	No	Yes
Arrival port	No	No	No	No	Yes	No
Linear week trend × ship fixed effect	No	No	Yes	Yes	No	Yes
Quadratic week trend × ship fixed effect	No	No	Yes	Yes	No	Yes
R^2	0.88	0.72	0.72	0.72	0.71	0.71
Sample size	13,536	13,536	13,536	13,536	11,058	11,058
Number of clusters (date × departure port × arrival port)	4,697					
Number of clusters (ships)		*N*	*N*	*N*	*N*	*N*

Notes. This table reports estimates of the effect of integration on TFP. The observations are at the trip level and include all trips of the Firm's ships or its long-term contractual suppliers. The variables are described in Table 1. The first model implements a cross-sectional estimation with detailed within-day controls but no ship fixed effects. The second, third, and fourth models include year-week dummies and ship fixed effects, with the number of ships (*N*) omitted for confidentiality. The fourth model includes three additional control variables. *Number of ships in fleet fishing this week* considers each firm's fleet (the Firm or its long-term suppliers) as distinct before integration but pools over all of them as a single firm after integration. *Number of third-party ships at this port* is the count of all distinct ships that are not the Firm's or its long-term suppliers' and that provide fish this week to the Firm's plant to which the ship arrives during this trip. *Number of third-party infractions in this area* is based on a registry of ship-trip level infractions for each firm in the industry and excludes any infraction of ships of the Firm or its long-term suppliers. The fifth and sixth models use the exact sample periods as those of the industry analysis in Table 2. Robust clustered standard errors are reported in parentheses. Robust standard errors are clustered by date-departure port-arrival port or by ship.

  **Significant at the 5% level; ***significant at the 1% level.

consistent with TFP gains. (Whether these gains may be attributed to the horizontal or vertical shift in integration is analyzed in §7.) Second, the number of weak-relationship and spot ships unloading fish at that port during that week captures local competition and sourcing strategies implemented by the Firm that may be conceptualized as an alternative driver of the focal ship's productivity. Finally, a third additional variable uses the number of fishing infractions committed by third-party ships (i.e., not the Firm's or its

long-term suppliers') in the specific geographic area of the destination port during the week in question. After introducing these additional variables, the effect of integration on TFP remains roughly similar, reflecting a 16.1% gain.

In the models just described, the data include all periods before and after the corporate acquisitions to assess the impact of integration on TFP. Because acquisitions occurred at different points in time (as detailed in §5.2), it is also useful to replicate the estimation using symmetric windows before and after integration to avoid concerns about biases in the treatment effect. In an untabulated regression, I find that estimating the fourth model of Table 3 using symmetric windows instead leaves the results largely unchanged.[11]

Panel B of Figure 1 displays kernel densities of TFP residuals for formerly contractual ships and owned ships, both before and after integration. The differential shift to the right for treated ships is comparable to the average treatment effect captured by the regression coefficients in Table 3.

How should a 16% increase in TFP be interpreted? First, although large if compared with an agnostic view of zero expected gains, it is not exorbitant (compared with, for example, Harris et al. 2005 study of TFP changes in a different context). Second, the estimate is obtained after considering many factors in a regression analysis not conducted by those responsible for the deals (as reported in §5.2). Third, even if doubting that such a large estimate of postmerger integration gains was unforeseeable, the only estimate available to decision makers involved in the corporate acquisitions before integration would have been a cross-sectional estimate like that of Model 3.1, a smaller value.

Given the TFP gains of integration into the Firm's fleet, it is illustrative to compare this causal estimate with the industrywide analysis of firm boundaries and productivity. The baseline analysis using data from the whole industry suggested no significant relation between vertical or horizontal ship status and productivity (Table 2). By contrast, analyzing the more specific (and possibly different) production environment of the Firm provides some advantages for identification and specification. First, the analysis based on the Firm exploits exogenous variation in firm boundaries (as detailed in §5.2). Second, the specification using the Firm's data includes fixed effects for routes and a microcontrol for factor utilization. To see these advantages more clearly, the fifth and

sixth models of Table 3 present results using similar specifications and sample periods. In the fifth column, the specification is exactly as in the industrywide analysis[12] (Model 2.3), yielding a significant coefficient estimate of 0.125; in the sixth model, which follows exactly the preferred specification for the Firm's data (Model 3.4), the coefficient estimate is 0.202. With the caveat that the larger treatment effects found in the preferred methodology may be specific to the clean sample analyzed, the comparison helps understand the quantitative contribution offered by the empirical design.

7. Mechanisms

Having found a robust causal impact of integration on TFP, I next explore the mechanisms explaining such impact. This exploration hinges on two premises. First, the effects of integration may follow different channels. Second, confronting these specific theoretical explanations can be fruitful, as they may be more broadly present beyond fishing. Because of space constraints, I provide a more detailed unifying interpretation of these tests in §7.5.

7.1. Assessing the Importance of Horizontal Scale

Could the positive coefficient of β in specification (7) be due to an horizontal scale argument reflected in the increased fleet size enacted by integration? This mechanism for the effect of integration—the enlarged horizontal scale of a fleet—appears to be different from a vertical mechanism guiding a ship's relation with downstream plants, as it would arise from better risk management and shared efficiencies in the process of finding and extracting fish. In the sample of interest, all acquired ships were already part of multi-ship fleets before the acquisition events. The acquisitions implied both vertical and horizontal integration changes for the external fleets, yet from a conceptual standpoint, their horizontal scale is changing in degree while their vertical scope is changing in nature.[13]

To supplement the results of Table 3, I explore the horizontal scale conjecture, introducing a different source of exogenous variation more directly related to horizontal scale changes. Even if this quest fails to find significant productivity gains from the horizontal scale, it may still be inappropriate to claim that

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[11] In another untabulated test, I also ran the fourth model of Table 3 separately for the two sets of acquisition events, finding almost exactly the same coefficient estimate for integration but more statistical power in the late set, an unsurprising pattern, given the information discussed in §5.2.

[12] Because the Firm acquired suppliers with fleets that included multiple ships, the horizontal integration dummy of Table 2 is absorbed in the Firm's sample by ship fixed effects.

[13] Because the same source of exogenous variation from acquisitions shifts both dimensions of integration, it is inadvisable to distinguish their effects in (7) using an interaction term between integration and number of ships in the fleet, as the results would be hard to interpret; such untabulated model yields a positive value β and a negative interaction coefficient.

there are no horizontal integration effects. Rather, it is plausible that the shift in integration drives changes through some other horizontal channel (further analyzed in §7.3), as would be expected in corporate hierarchies with multiple production units both upstream and downstream.

To address the horizontal scale conjecture, I employ different tests in subsamples of the Firm's data. First, I consider the already owned ships of the Firm as the treated group around the fleet acquisitions conducted by the Firm and compare them to a similar set of ships of vertically integrated firms whose horizontal scale does not change. Second, I focus on the long-term contractual suppliers of the Firm during periods *before* the integration acquisitions took place and exploit exogenous variation in their horizontal scale stemming from affiliated ships' suspensions. The common theme of these two kinds of tests is the analysis of whether, after holding vertical integration fixed (i.e., all sample ships either vertical integrated or vertically unintegrated), horizontal scale has a noticeable impact on TFP.

The first and second columns of Table 4 report the first set of results. The acquisition of additional fleets by the Firm increases the size and the capacity of the fleet of already owned ships of the Firm, but these changes do not have a statistically significant impact on their productivity. Put differently, if horizontal scale (as captured by the number of ships in a fleet) were the main driving force of the productivity gains reported in Table 3, that channel would also be effective in increasing the productivity of the Firm's already owned ships, whose horizontal scale certainly grew with the acquisitions. No productivity increase, however, is found in the first two models of Table 4.

In the second set of tests, I exploit fishing suspensions of *other ships of the same fleet* as a source of exogenous variation to the horizontal scale of a given ship. The regulatory authority punishes ship infractions with days of suspension of their fishing license. Theoretically, a ship's captain may act rationally when assessing the chances of being suspended according to an individual profit function (Furlong 1991). Yet these actions can be plausibly considered exogenous to the individual profit function of other ships of the same fleet.[14] Suspensions only last a few days, yet they constitute clear reductions in the horizontal scale of a ship's fleet. The third and fourth model of Table 4 include the count of ships suspended and the capacity of ships suspended as explanatory variables of TFP

among the vertically unintegrated long-term suppliers of the Firm in periods before they were acquired. (For clarity, the control variable *number of ships in the fleet fishing this week* is excluded from these models, as this variable is unsurprisingly negatively correlated with the exogenous scale variables introduced.) The results indicate no statistically significant change in TFP effected by these changes in horizontal scale.

Although these tests of the horizontal scale conjecture are suggestive, it is possible that horizontal integration operates through other channels. For example, an informational advantage in searching for fish has been long advanced as a positive feature of large fleets; in the case of the Firm, qualitative evidence suggests that much information already flowed within and across firm boundaries, as ship captains shared information with one another regardless of their different affiliation (see Palmer 1991 for an example in a different setting). Horizontal affiliation may also bring about changes through shared knowledge of fishing practices, as examined in §7.3.

7.2. Heterogeneous Effects of Integration Across Characteristics

Well-known arguments in the literature suggest that the effect of firm boundaries on performance depends on the types of transactions involved (Lafontaine and Slade 2007). Table 5 shows whether the types of trips, ships, and crews influence the productivity consequences of integration.

7.2.1. Tests of Hold-Up Alleviation. First, I use heterogeneity in transactions to develop various tests of hold-up risk in fish-sourcing relationships (e.g., Johnson and Libecap 1982, Koss 1999). Recall from §2.2 that one source of potential hold-up originating in ship workers' behavior is assuaged by the lay system of pay, yet hold-up may arise from plant owners exerting strategic pressure on ship owners in their interactions. As a first test of hold-up, the first model of Table 5 analyzes the impact of integration on the queuing wait time of arriving ships. (This wait dependent variable is different from TFP but fits better the discussion here than later in this section.) Anecdotal evidence suggests that queuing could be a source of vertical frictions in this industry in general. Interviews with the Firm's officers, however, suggest that the Firm prided itself for treating both integrated ships and contractual ships equitably regarding wait times. Although I cannot test the industrywide conjecture about queuing, I do test it in the context of the Firm and find that integration does not reduce wait times. The point estimate in the first model of Table 5 is statistically insignificant, suggesting that this type of hold-up risk is not present in this sample.

In a second test of hold-up, I interact the dummy for integration with a nonresaleability measure defined as

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[14] See Hatcher et al. (2000) for an alternative model that considers a social factor in the decision to violate fishing regulations; even in such alternative theoretical model, violations of one ship captain are not related to violations of another ship in the same fleet. To my knowledge, no other model suggests such cross-ship connection.

Table 4   Total Factor Productivity and Exogenous Horizontal Scale Changes in Vertically Uniform Fleets

Dependent variable:	Log(*Output*)			
	Panel A		Panel B	
Sample ships:	Vertical ships only		Long-term suppliers' ships only	
Sample period:	Before and after Firm's acquisitions		Only before integration	
	(4.1)	(4.2)	(4.3)	(4.4)
Size of own fleet	0.002			
	(0.00)			
Capacity of own fleet		0.005		
		(0.01)		
Supplier fleet's number of ships suspended			0.017	
			(0.03)	
Supplier fleet's capacity of ships suspended				0.000
				(0.00)
Log(*Use*)			0.035	0.035
			(0.02)	(0.02)
Fuel price	0.689	0.689	−0.320	−0.334
	(1.52)	(1.52)	(0.59)	(0.59)
Ban on anchovy	−0.281***	−0.281***	−0.210*	−0.205*
	(0.06)	(0.06)	(0.11)	(0.11)
Ban on white anchovy	0.133	0.133	0.100	0.096
	(0.13)	(0.13)	(0.11)	(0.11)
Announced ban on anchovy	−0.338***	−0.338***	−0.025	−0.025
	(0.10)	(0.10)	(0.09)	(0.09)
Announced ban on white anchovy	0.345***	0.345***	−0.032	−0.031
	(0.10)	(0.10)	(0.09)	(0.09)
Fishing for fishmeal	0.899***	0.899***	−0.018	−0.018
	(0.12)	(0.12)	(0.02)	(0.02)
Number of third-party ships at this port, this week	0.002	0.002	0.001	0.001
	(0.00)	(0.00)	(0.00)	(0.00)
Number of third-party infractions in this area, this week	0.001	0.001	0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)
Fixed effects:				
Ship	Yes	Yes	Yes	Yes
Year–week	Yes	Yes	Yes	Yes
Arrival port	Yes	Yes	No	No
Departure port × fishing port × arrival port	No	No	Yes	Yes
Linear week trend × ship fixed effect	Yes	Yes	Yes	Yes
Quadratic week trend × ship fixed effect	Yes	Yes	Yes	Yes
R^2	0.64	0.64	0.56	0.56
Sample size	3,844	3,844	5,453	5,453
Number of clusters (ships)	J	J	K	K

Notes. This table reports two different kinds of models (panels A and B) of the impact of horizontal scale on TFP in subsamples closely related to the main sample of the study. Panel A includes observations on all vertical ships of the Firm already owned when the acquisitions of long-term suppliers occurred and all ships of other vertically integrated ships that do not expand their fleets during that time window. Size of fleet owned is the count of ships in each fleet, a number that only varies for the Firm; analogously, capacity of fleet owned in this sample of always-vertical ships is the sum of fleets' hold capacity, which only varies for the Firm because of the acquisition of long-term suppliers. Panel B follows Model 3.4 of Table 3, including only the ships of the long-term suppliers of the Firm that eventually were acquired by the Firm but during the periods before they became integrated. Suspensions enacted by the regulator's sanctions of any of the fleets' violations generate the horizontal scale variables of interest. The third model uses the count of the fleet's ships suspended that day as the explanatory variable; the fourth model uses the sum of the hold capacity of those suspended ships as the explanatory variable. Standard errors are heteroskedasticity-robust and clustered by ship.

  *Significant at the 10% level; ***significant at the 1% level.

the Herfindahl index for each fish species in relation to all processing plants across the industry that historically bought it. Species with a higher nonresaleability index are thus less resaleable.[15] Consistent with the

existence of hold-up, the second column of Table 5 suggests that integration increases productivity when the fish species is more rarely demanded.

In contrast to the second test of hold-up, a third test (further described in §7.4; see the second column of Table 7) indicates that the Firm increases the proportion of fishmeal (i.e., anchovy) trips of newly

[15] For example, anchovy has a nonresaleability index value of 0.01, whereas pike needle fish has an index value of 1.

Table 5 Heterogeneous Impact of Integration on Total Factor Productivity

Dependent variables:	Log(*Wait*)	Log(*Output*)					
	(5.1)	(5.2)	(5.3)	(5.4)	(5.5)	(5.6)	(5.7)
Integrated ship	0.032 (0.10)	−0.051 (0.07)		0.104 (0.07)	0.090 (0.07)	0.203*** (0.06)	0.172*** (0.06)
Integrated ship × Nonresaleability index		2.461*** (0.80)					
Postintegration date × The Firm's own ships			−0.046 (0.12)				
Integrated ship × Large ship				0.093* (0.05)			
Integrated ship × Powerful engine					0.110* (0.06)		
Integrated ship × Old captains						−0.091* (0.05)	
Integrated ship × Highly educated							−0.030 (0.05)
Other controls as in Model (3.4)	Yes	Yes	~Log(*Use*)	Yes	Yes	Yes	Yes
Ship fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year–week fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Departure port × fishing port × arrival port	Yes	Yes	No	Yes	Yes	Yes	Yes
Arrival port			Yes				
Linear trend × ship fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quadratic trend × ship fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.24	0.73	0.64	0.72	0.72	0.72	0.72
Sample size	7,186	13,536	3,844	13,536	13,536	13,536	13,536
Number of clusters (ships)	*K*	*N*	*J*	*N*	*N*	*N*	*N*

Notes. This table reports the impact of integration on queuing wait time and the effects of integration on TFP depending on cross-trip and cross-ship characteristics. All models except the third expand on the fourth model of Table 3. The third model exclusively uses observations on the Firm's already owned ships and ships of other vertically and horizontally integrated firms that did not undergo vertical acquisitions, so it does not include a granular control variable for the use of inputs, as it is not available for those firms. The *nonresaleability index* is equal to the Herfindahl index for each fish species in relation to all processing plants across the industry that historically bought it; for example, anchovy is the most common species and has a nonresaleability index value of 0.01, whereas species with just one buyer have an index of 1. *Large ship* is a dummy for above-median ship capacity. *Powerful engine* is a dummy for above-median engine power. *Old captains* is a dummy for captain and chief mate above median age at the moment of integration, and *highly educated* is for above-median schooling. Separate coefficients on the interaction variables are either subsumed by the fixed effects or not displayed for brevity. Other coefficients as in the fourth model of Table 3 are not displayed here for brevity. Robust standard errors are clustered at the level of ships (with the number of ships *K*, *N*, and *J* omitted for confidentiality) and are in parentheses.

*Significant at the 10% level; ***significant at the 1% level.

integrated ships. If nonresaleability—and the hold-up threat it poses—were a primary friction hindering productivity, then the Firm would *increase* the proportion of nonanchovy trips, thus *reducing* the proportion of fishmeal trips during the postintegration period, contrary to what I find.

Last, a fourth set of tests may also help assess whether hold-up alleviation enhances TFP under integration. As reported in §7.3 when discussing the ninth model of Table 6, the transfer of catches to the Firm rather than to other buyers significantly increased after integration. Yet this pattern may not indicate an increased guarantee to receive fish under integration. The full tabulation of this sale-to-third-parties test (and variants), omitted here for brevity, shows that the Firm's decision to source from other suppliers is not positively correlated with the sale-to-third-parties behavior of the ships of interest. As is also reported in §7.4, the Firm reduced its sourcing from

weak-relationship parties after integration, but this aggregate pattern may be better interpreted as an outcome rather than an ex ante threat, in light of the evidence of ships' sale to third parties and plants' sourcing behavior.

7.2.2. Tests of Displacement, Human Capital, and Asset Quality. A different explanation for the positive impact of integration on TFP considers whether the Firm's already integrated ships may be displaced by the newly integrated ships (e.g., Schoar 2002). Because the results in §6 use only data on the Firm's ships and its long-term suppliers, any gain of the latter group is measured in relation to the former. The third model of Table 5 implements a difference-in-differences approach in which the treated group is formed by the already owned ships of the Firm and the control group is formed by all ships of *integrated firms other than the Firm* that did not pursue vertical

Table 6   **Integration and Real-Time Within-Trip Operations**

Dependent variable:	Distance	Mean speed	Std. dev. of speed	Neighbor separation	Firm neighbor separation	Number of tries	Distance to prior fishing area	Meander ratio	Sale to third parties
	(6.1)	(6.2)	(6.3)	(6.4)	(6.5)	(6.6)	(6.7)	(6.8)	(6.9)
Integrated ship	0.094**	0.094**	0.082*	0.054	−0.365*	−0.038	−0.173**	−0.081**	−0.062***
	(0.04)	(0.04)	(0.05)	(0.10)	(0.21)	(0.03)	(0.07)	(0.04)	(0.02)
Other controls as in Model (3.4)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects:									
Ship	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year–week	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Departure port × fishing port × arrival port	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Linear trend × ship fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quadratic trend × ship fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.88	0.53	0.47	0.56	0.63	0.74	0.31	0.25	0.29
Sample size	13,536	13,536	13,536	13,533	13,511	13,536	13,536-N	13,492	13,536
Number of clusters (ships)	N	N	N	N	N	N	N	N	N

Variance test for newly integrated ships, *p*-value:
  SD(vertical integration) ≤
    SD(nonvertical integration)
	0.51	0.09	0.00	0.00	0.00	0.58	0.00	0.00	N.A.

Notes. This table reports models of the impact of integration on within-trip operations in real time. The observations are at the trip level and include all trips of the Firm's ships or its long-term contractual suppliers. All dependent variables are in logarithms and described in Table 1. All explanatory variables are as in the fourth model of Table 3 but not displayed here for brevity. Robust standard errors clustered by ship are in parentheses.
  *Significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.

acquisitions in a comparable period (with the number omitted for confidentiality). As seen in the third model of Table 5, there is no statistically significant productivity change among the Firm's already owned ships after the integration events, suggesting no evidence of displacement.

Last, I test whether the impact of integration on TFP differs across ship size and engine power and across ship captain age and education. The results of these interaction tests (all of which also include the interaction variable alone when not absorbed by the ship fixed effects) are reported in the last four columns of Table 5. Larger and more powerful ships achieve higher TFP levels after integration; similarly, ships with younger captains become more productive. Interestingly, the pre-integration level of captain education does not matter for postintegration TFP. This heterogeneity in the benefits of integration is consistent with Suri's (2011) explanation for why firms may not pursue a productivity-enhancing change, even when knowing some of its benefits and costs.

7.3. Integration and Real-Time Within-Trip Operations

Integration of formerly external fleets into the Firm may enact profound operational changes through the establishment of a common hierarchical structure and the transfer of knowledge within it (Dessein 2002, Garicano and Rossi-Hansberg 2006, Marino et al. 2010, Van den Steen 2010). In this section, I explore

this mechanism by constructing GIS-based variables.[16] First, I employ these operational constructs as dependent variables at the trip level for different kinds of tests. Second, I conduct a graphical analysis of TFP changes in relation to these operational practices.

Table 6 displays the first set of results. The first and second columns show that, under integration, formerly contractual ships travel longer distances and conduct their trips at higher speed.[17] Because the specification controls for the duration of the trip (i.e., use), an increase in distance traveled is tantamount to an increase in speed. Moreover, as displayed in the third column of Table 6, integration increases the variance in the speed of ships. These mobility patterns suggest that integration increases the thoroughness in covering fishing areas and also impacts navigation smoothness.[18]

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[16] Though ideally I would have liked to use standard variables from the oceanography or marine biology literatures, there is little prior art in modeling fishing dynamics with satellite data (van Putten et al. 2012). Thus, I construct measures of fishing practices based on my own understanding and field research.

[17] See Table 7 for aggregate results on how integration increases the share of fishmeal trips.

[18] Given the longer distances traveled by integrated ships and the different species caught, do TFP gains represent higher profitability? First, although cost data are not available for external ships before integration, in untabulated models I conducted out-of-sample predictions to fill in this cost series using the available operational data as well as complete revenue data. Based on this analysis, profitability seemed to significantly increase (in dollar terms) for newly integrated ships after accounting for all the monetary expenses of fishing operations. Second, just by focusing on

The fourth and fifth model of Table 6 show whether the geographical density of ships changed substantially in relation to other ships. The fourth column shows no significant increase in the average distance with respect to the nearest neighbor within the fleet to which the ship belongs. The fifth model of Table 6 shows a negative effect of integration on a ship's separation with respect to the nearest ship of the Firm. Integration appears to enact a more focused deployment of ships.

Does integration lead to more effort within a trip?[19] The sixth column of Table 6 indicates that this is not so, as ships do not make more attempts ("fishing sets") at casting their nets to catch fish.

The last three columns of Table 6 model how integration affects other operational decisions. In the seventh column, the regression uses the distance with respect to the prior trip's extraction area as the dependent variable, showing a negative and significant coefficient on integration. Newly integrated ships thus become more persistent in their attempts to find fish. The eighth column of Table 6 employs the ratio of the distance traveled in the return trip divided by the straight line between the return point and the arrival port; this "meander ratio" is significantly reduced by integration, suggesting that ships are returning to their plants more promptly. On arrival, moreover, newly integrated ships show a greater tendency to transfer their goods to the Firm than to third parties, as displayed in the last model of Table 6. Overall, these results suggest that integration leads to more persistence in localized fishing, more disciplined return trips, and more exclusive internal transfers of output.

In addition to measuring the average operational changes in Table 6, I also test for changes in the second moments of these operational practices. Variance ratio tests (Brown and Forsythe 1974) for the newly integrated ships, reported at the bottom of Table 6, indicate that in nearly all cases,[20] the variance of the operational practices of interest increased during the integration regime. This pattern suggests that the changes mandated by the Firm are not uniform for all newly acquired ships and may sometimes include

specific orders that go against the temporary interest of individual operators.[21]

Which of the various practices in Table 6 matters the most for gains in TFP under integration? I construct a TFP residual at the ship level for each of these ships in the periods both before and after integration and then correlate the increment in TFP residuals with the changes in operational practices before and after integration. Figure 2 (with details in its caption) displays fractional polynomial graphs for the variables that were significantly affected by integration in Table 6. The results of this analysis indicate that distance to prior area, return meandering, and sale to third parties are constructs pointing in a consistent direction in the regression analysis of Table 6 and in the graphical analysis of Figure 2, suggesting that these practices create value. It is important to note that Figure 2 also suggests that some operational changes may hurt TFP. Thus, the Firm did not have to choose a perfect set of actions, nor implement some actions perfectly, to achieve a large average TFP gain.

Last, how were these operational changes enacted inside the Firm's integrated structure? Qualitative evidence suggests that the role of the Firm's managers on land was crucial to bring ship operators in line with the procurement needs of the plants, as well as to agree on search, deployment, and operational practices. For example, coordination meetings at the beginning of each fishing season served as a vehicle to communicate fishing tactics. Before integration, the captains of long-term supplier ships were invited to these meetings with the Firm's managers but did not regularly attend.

7.4. Integration and Aggregate Deployment
Thus far the analysis has been conducted at the trip level. Alternatively, it is also important to assess how other aggregate patterns change with integration and whether those changes are consistent with the fine-grained trip-level results. To do this, Table 7 presents an analogous difference-in-differences specification at the more aggregate level of each ship-year combination.

The results of Table 7 suggest that the Firm increases the operational focus of newly integrated ships and transfers knowledge about integrated operations without altering their number of trips, their output volatility, or their geographical variability. (All dependent variables are defined in the caption of Table 7.) The first model shows no statistically significant impact of integration on the total number of trips

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the postacquisition period, I found a very high correlation (e.g., above 92%) between TFP residuals of the models presented here and expanded-factor TFP models using more detailed information on material expenses such as fuel and maintenance services. Overall, the evidence is consistent with a significant increase in profitability attributable to integration.

[19] A different dimension in which effort might change is the extensive margin, that is, whether ships started fishing more often after integration. As shown in Table 7, I find no significant effect of integration on the frequency of trips.

[20] Sale to third parties does not yield a meaningful variance ratio test because it is a binary dependent variable.

[21] In untabulated regressions extending the specification of Table 6 to include an additional interaction term for postintegration during the first year, I find that most operational practices immediately changed under integration, but a few (i.e., meander ratio, sale to third parties) took longer to implement.

Figure 2   Relating Changes in Ship Total Factor Productivity to Changes in Within-Trip Operations
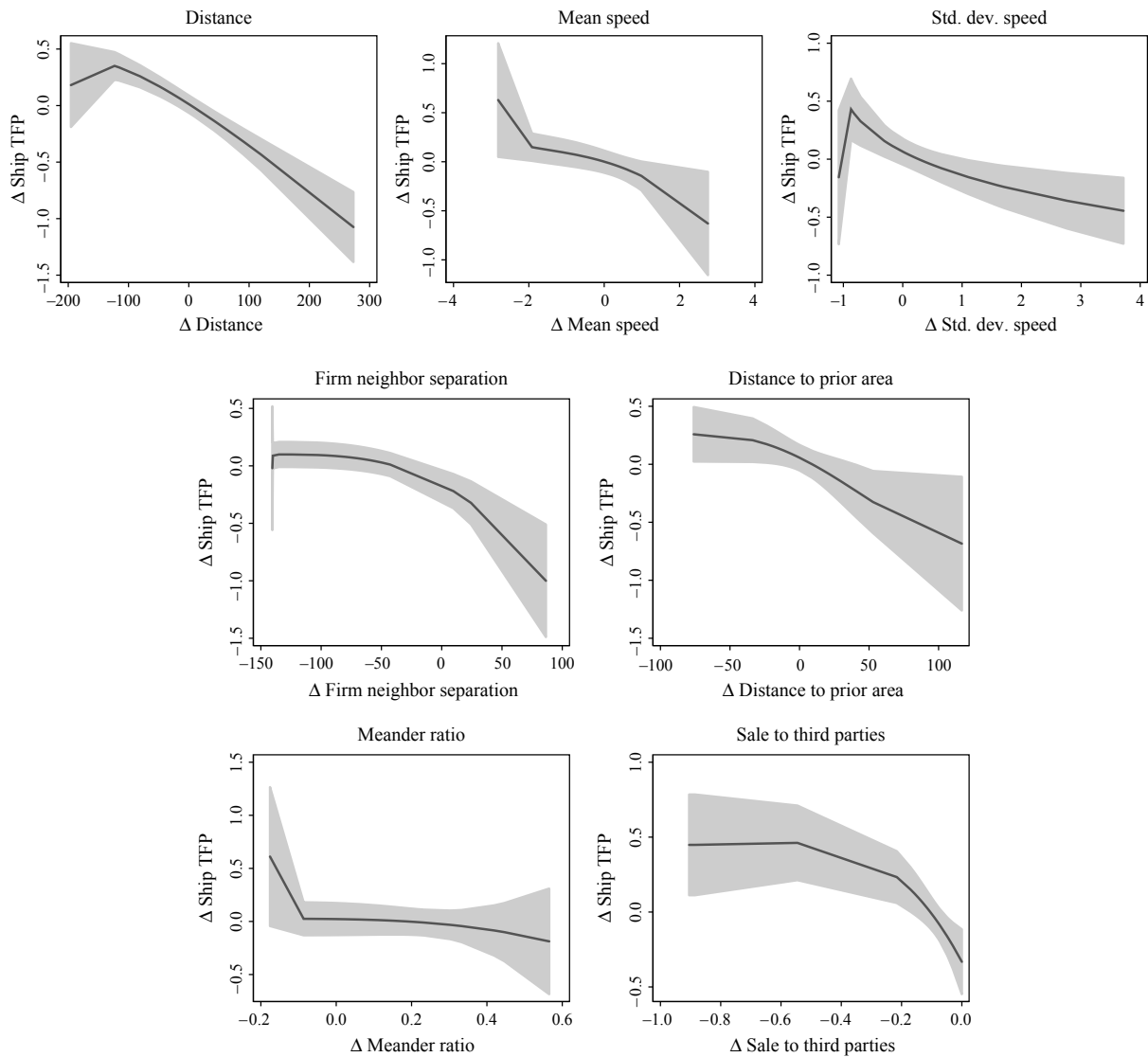
Notes. The sample for the graphs consists of long-term contractual ships before and after they become integrated into the Firm. Each graph presents a fractional polynomial fit of changes in ship-level TFP on changes in ship-level trip operating variables, with 95% level confidence intervals shown in gray shades. The estimation summarizes all inputs, outputs, and operations for these ships before and after integration, thus obtaining two observations per ship i to estimate the regression

$$y_{it} = \beta_1 * l_{it} + \beta_2 * k_{it} + \beta_3 * u_{it} + \alpha * 1(t = \text{post}) + \epsilon_{it}.$$

For each ship-period observation, ship TFP is defined as the residual $\hat{e}_{i,t} = y_{it} - \hat{y}_{i,t}$ using the above regression coefficient estimates. For each ship, the increment of this productivity residual is defined as Δ Ship TFP$_i = \hat{e}_{i,\text{post}} - \hat{e}_{i,\text{pre}}$ and plotted in the vertical axis of each graph. The horizontal axis measures the increment in an operating variable in the period after integration with respect to the period before integration for each ship.

made by a ship, thus offering a useful confirmation of productivity gains happening at the trip level in the main results. The second column indicates a positive effect of integration on the share of fishing trips that are conducted for fishmeal. Operationally, fishing-for-fishmeal trips require more focused geographical deployment than fishing-for-seafood trips, which instead entail searching for more sparsely distributed species. In untabulated models explaining profitability (instead of TFP) following integration, I find no statistical difference between how integration affects

fishmeal trip profitability versus seafood trip profitability; hence, the relative economic attractiveness of these kinds of trips remains the same after integration. I thus interpret the increase of fishmeal trips as a tighter geographical proximity strategy that helps integrate newly acquired ships into the Firm.

The third model shows no change in the coefficient of variation of catch weight. The fourth model reports no significant impact of integration on the concentration index of routes used by a ship in a given year. The fifth column of Table 7 indicates that,

Table 7 **Integration and Aggregate Deployment Decisions**

Dependent variable:	Number of trips	Share of trips for fishmeal	Output coefficient of variation	Concentration of routes	Share of expedition companions of same fleet origin
	(7.1)	(7.2)	(7.3)	(7.4)	(7.5)
Integrated ship	−0.296	0.196***	−0.018	0.055	−0.153***
	(7.13)	(0.06)	(0.09)	(0.08)	(0.04)
Fixed effects					
Ship	Yes	Yes	Yes	Yes	Yes
Relative year	Yes	Yes	Yes	Yes	Yes
Linear trend × ship fixed effect	Yes	Yes	Yes	Yes	Yes
Quadratic trend × ship fixed effect	Yes	Yes	Yes	Yes	Yes
R^2	0.76	0.94	0.53	0.88	0.94
Sample size	311	311	311	311	310
Number of clusters (ships)	N	N	N	N	N

Notes. This table reports estimates of the effect of integration on aggregate deployment decisions. The observations are at the ship-year level and include all trips of the Firm's ships or its long-term contractual suppliers. Years are not expressed in calendar time but in time relative to the last acquisition event conducted by the Firm; one relative year includes trips 365 days before or after that event. *Number of trips* is a simple count. *Share of trips for fishmeal* is the ratio of all trips of the ship conducted with the purpose of catching fish for fishmeal. *Output coefficient of variation* is the ratio of the standard deviation of catches divided by the mean of catches. *Concentration of routes* is the Herfindahl index, bounded between 0 and 1, based on the yearly count of the ship's λ routes, with routes as defined in Equation (7). *Share of expedition companions of the same fleet origin* is based on all ships other than the focal ship that were part of the same expedition of the ship across all expeditions throughout the year; ships in an expedition are defined as those present in the same fishing area on the same day; the fraction of these ship-expedition combinations that has the same fleet ownership origin as the ship is the variable of interest. Robust standard errors clustered by ship are in parentheses.

***Significant at the 1% level.

under integration, formerly external ships reduce their expedition-specific collaboration with other originally affiliated ships and start collaborating more with the ships of formerly different fleets, some of which are those of the Firm.

Finally, I also assess whether the productivity gains found throughout the analysis matter for the broader procurement strategies of the Firm. In untabulated tests, I find that the share of total fish procured from weaker-relationship and spot ships decreases after integration. The Firm thus likely uses its integration gains for market substitution rather than for increased market power.

7.5. Unifying Discussion of Mechanisms

Even when a main effect is statistically identified, the interpretation of causal mechanisms is limited by the availability of exogenous variation behind all mechanisms. With that caveat, I link the results in §7 with the main finding of TFP gains under integration. I start assessing evidence of classic explanations. First, the TFP gains identified are not mechanical losses of already integrated ships (Model 5.3). Second, evidence on horizontal scale impacting TFP without the vertical shift in integration is weak (Table 4). Third, hold-up risk does not systematically affect TFP and operational gains (contrast Model 5.2 with Model 7.1, Model 5.4, and Model 6.9 fully tabulated), and effort is not consistently higher under integration (Models 6.1–6.3 and 6.6); nor does it explain TFP gains (Figure 2).

By contrast, the evidence more strongly suggests that newly integrated assets implement more focused operational practices (Model 7.1 and Models 6.5–6.9), some of which correlate well with higher TFP (Figure 2). To transfer knowledge about these practices, the Firm's existing ships start interacting more closely with the newly acquired ships in coordination with plants (Model 7.4). The adoption process is also of some interest. Operational practices are not uniformly implemented by all newly acquired ships (variance tests in Table 6), suggesting a compromise of some units for the benefit of the overall firm. Some of the formerly unintegrated ships or their captains are not well suited for more productive operations (Models 5.5–5.8). And some of the operational practices are implemented quickly but others prove harder and slower to enforce (untabulated timing tests reported in §7.3). Overall, the process does not increase output variability for a given ship (Model 7.2), nor does it hurt already integrated ships through displacement (Model 5.3).

The results raise interesting questions regarding why these productivity-enhancing practices were not adopted before integration. Answers from additional field research remain partial. External operators seemed to have different opinions and beliefs about the upside of these operational policies. For example, the evidence indicates that not all operational changes brought about by integration increased productivity. Perhaps the Firm was unwilling to share its valuable knowledge of some practices with its suppliers to benefit its own ships or was unable to demonstrate their value without authority. After corporate acquisitions shifting the integration status of external fleets were

announced, the Firm's managers implemented these practices in their newly integrated ships. Productivity gains ensued from enhanced knowledge transfer and hierarchical authority channeled through integration.

8. Conclusion

In this study, I use granular data to assess the causal impact of integration on total factor productivity. Firm boundary decisions may have profound implications for performance, but integration is, in general, an endogenous choice of the firm. I exploit plausibly exogenous variation in the corporate ownership of fishing fleets to study the effect of integration on TFP. The results indicate a positive, statistically significant and economically large influence of integration on TFP. The study also offers suggestive evidence linking the real-time operations of assets during production with mechanisms explaining the productivity gains of integration. Some classic arguments such as hold-up threat alleviation and increased effort due to monitoring do not systematically explain TFP gains under integration. Rather, enhanced knowledge transfer and hierarchical authority enacting productivity-improving practices are more likely explanations of the results.

Integration is not simple addition or juxtaposition, but organic cohesion that shapes identity. Recent research has proposed that the gains through which integration affects productivity may be the transfer of intangibles rather than physical goods. This paper offers a new perspective by proposing that hard asset operations change substantially after integration, possibly because of soft knowledge transfer mechanisms that are better enacted under the hierarchical authority structure of the corporation. Methodologically, this study also introduces TFP and GIS into the broader discussion of the vertical, horizontal, and geographical boundaries of the firm, all core dimensions of corporate strategy.

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