Vertical Integration, Supplier Behavior, and Quality Upgrading among Exporters*

Christopher Hansman
Columbia University

Jonas Hjort
Columbia University & BREAD & NBER

Gianmarco León
Universitat Pompeu Fabra & Barcelona GSE & IPEG

Matthieu Teachout
Columbia University

September 4, 2017

Abstract

We study the relationship between exporters' organizational structure and output quality when contracts are incomplete. Using quality grade specific production data and the sales and supply transactions of Peruvian fishmeal manufacturers, we show that vertical integration causally increases output quality, and that manufacturers integrate when facing high relative demand for high quality grades. To understand why, we use data on supplier (fishing boat) behavior. A quality-oriented manufacturer's independent suppliers can sell to others. As theory predicts, integrating thus helps incentivize input quality-increasing-but-quantity-decreasing behavior. Finally, we show that the identified integration-quality relationship appears to hold on average in export manufacturing industries.

JEL codes: D2, O1

*cjh2182@columbia.edu, hjort@columbia.edu, gianmarco.leon@upf.edu, mrt2138@columbia.edu.

We thank Charles Angelucci, David Atkin, Wouter Dessein, Bob Gibbons, Marina Halac, Amit Khandelwal, Rocco Macchiavello, Ameet Morjaria, Andy Newman, Andrea Prat, Eric Verhoogen, Daniel Wolfenzon, and Xiao Yu Wang for very helpful comments and suggestions; seminar participants at Columbia, UPF, LSE, the NBER Working Group on Organizational Economics, the 2015 Summer School in Development Economics (SSDEV), and the 2016 IGC/Stanford SCID conference on Firms, Trade and Development; and Patrick Kennedy and Leonor Lamas for great research assistance and field work. The Peruvian Ministry of Production and Cesar Casahuamán kindly shared access to data. León acknowledges financial support from the Spanish Ministry of Economy and Competitiveness, through the Severo Ochoa Programme for Centres of Excellence in R&D (SEV-2015-0563) and grant ECO2014-55555-P.

1 Introduction

Why do so many of our economic transactions occur within firm boundaries (Antràs, 2003; Lafontaine & Slade, 2007)? Research on this question goes back to Ronald Coase's seminal contributions. The contracting issues emphasized in the body of theoretical work following Coase (1937) are especially prominent in environments where firms attempt to source *high quality* inputs (see Gibbons, 2005). This suggests that upgrading output quality—an essential element of export-driven economic development[1]—may be an overlooked motivation for vertical integration.

Sourcing of high quality inputs frequently entails two contracting challenges stressed in the literature. First, quality grade is notoriously difficult to contract upon (Williamson, 1971, 1975; Grossman & Hart, 1986; Hart & Moore, 1990), especially in developing countries (Nunn, 2007; Macchiavello & Miquel-Florensa, 2016). Second, the process of producing inputs often involves the sort of complex multitasking studied in Holmstrom & Milgrom (1991); Holmstrom & Tirole (1991); Holmstrom (1999), which may restrict how manufacturers can incentivize a specific form of supplier behavior (Baker *et al.* , 2002). Industries where downstream firms produce vertically differentiated products thus provide an unusual opportunity to directly test mechanisms at the core of classical theories of the firm.

In this paper we study the relationship between organizational structure and output quality. We hypothesize that (i) vertical integration represents a strategy potential exporters use to produce goods of high quality, and (ii) this is because, when contracts are incomplete, owning the productive assets used by suppliers enables firms to incentivize the supply of high quality inputs. The first part of our hypothesis implies that vertical integration (X) is both *effective* as a strategy for producing high quality output (Y) ($X \rightarrow Y$) and *used as such* ($X \leftarrow Y$). Testing the hypothesis thus requires separately identifiying how vertical integration affects output quality and how (demand for) output quality affects vertical integration.[2]

We investigate these questions in the context of one of Latin America's largest industries: fishmeal manufacturing in Peru.[3] We first establish how the quality grade of a firm's exports differ when the firm owns more of its suppliers (fishing boats), and when a higher share of its plants' input is coming from integrated suppliers (*effectiveness*). To instrument for the integrated share of a plant's supply, we exploit leave-firm-out variation across time in the presence of independent suppliers supplying a cluster of plants. We then explore if Peruvian manufacturing firms acquire suppliers and source a higher share of their input internally when the composition of demand shifts toward high quality grade goods (*use*), instrumenting for firm specific demand with foreign demand shocks. Finally, we investigate *why* integration may enable quality upgrading, focusing on firms' ability to incentivize desired supplier behavior and comparing integration also to other alternatives to the spot market such as repeated interactions. To guide the investigation, we adjust the Baker *et al.* (2002) model to allow for both quantity- and quality-oriented downstream firms, and supplier quantity- and quality-increasing actions. Finally, we use "switchers"—i.e., supplier-plant pairs that transact both as independent and integrated entities—and exogenous variation in production conditions to

[1] An existing body of literature documents that inputs of the desired specifications help downstream manufacturers in poor countries produce goods of the targeted output quality level and export to more profitable, richer countries (see, among others, Hallak, 2006; Verhoogen, 2008; Brambilla *et al.* , 2012; Kugler & Verhoogen, 2012; Manova & Zhang, 2012; Bastos *et al.* , 2016).

[2] One direction of causality may confound (conjectured) evidence supporting the relevance of the other if the two are not separately identified. In general, the data and variation needed to identify *both* (a) the effectiveness of a firm strategy and (b) the determinants of its use is rarely available. Most existing studies therefore restrict attention to either (a) (see e.g. McKenzie *et al.* , 2008; Bloom *et al.* , 2013; Hardy & McCasland, 2015) or (b) (see e.g. Bastos *et al.* , 2016; Park *et al.* , 2009; Brambilla *et al.* , 2012).

[3] Fishmeal is a brown powder made by burning or steaming fish, and often used as animal feed. Peru's fishmeal industry—the biggest in the world—accounts for around 3 percent of the country's GDP (Paredes & Gutierrez, 2008; De La Puente *et al.* , 2011).

show how integration status affects supplier behavior.

Peru's fishmeal sector is an ideal setting to study the relationship between organizational structure and output quality for several reasons. First, fishmeal is a vertically differentiated but otherwise homogeneous product. The quality of its primary input—fish—is difficult to contract upon. The presence of outside options—alternative downstream buyers who may value input quality less—gives suppliers incentives that represent a challenge for plants trying to produce high quality fishmeal by buying inputs on the spot market.

Second, we directly observe output quality. Public inspectors monitor manufacturing firms' monthly reports of each plant's output of both "fair average quality" (low protein content) and "prime" quality (high protein content) fishmeal. Furthermore, because we observe the price prevailing across the full range of protein content in a given week×export port in granular data from a fishmeal consulting firm, we can infer a continuous measure of each export shipment's exact quality grade.[4] We thus avoid relying on quality measurement procedures that risk conflating quality with mark-ups and horizontal differentiation (see e.g. Khandelwal, 2010; Hallak & Schott, 2011).

Third, we observe all transactions between plants and suppliers in data from Peru's authorities. Domestic transactions data are rare; observing the transactions of an entire industry, including within-firm transactions, is especially rare. In combination with plant production and customs data, the supply transactions data allow us to track the flow of goods across three different stages of a global value chain.

Fourth, acquisitions (and sales) of existing suppliers, and changes in the integrated share of a firm's inputs; the quality grade of its output; and foreign demand for quality all occur with relatively high frequency in the context we study. This allows us to provide what to our knowledge is the first evidence on the extent to which, and how, firms vary their organizational structure in order to produce goods of a targeted type.

Finally, we observe the behavior of suppliers. Fishing boats are required to transmit GPS signals to the regulatory authorities while at sea. We use GPS-based proxies for input quality- and quantity-increasing actions to explore how a supplier's behavior differs when integrated, exploiting independent-to-integrated and integrated-to-independent (within-relationship) switchers for identification. We also use daily measures of plankton concentration across 10×10 kilometer grid-cells of the ocean constructed from satellite images to test how suppliers' behavioral response to exogenous variation in the opportunity cost of producing inputs of high quality and quantity differs when integrated.

Our results are as follows. A firm produces considerably higher quality output and is paid higher export prices when it owns more of its suppliers. This relationship arises through input sourcing: output quality is higher when the firm's "share VI" (share of inputs coming from integrated suppliers) is higher at the time of production. "Share VI" and output quality co-vary also at plant level, where quality is directly observed. We can thus (i) rule out explanations due to how quality is measured or firm and firm×season level shocks (e.g. to productivity or demand) whose correlation with organizational structure (X) and output quality (Y) does not reflect a direct ($X \to Y$) effect, and (ii) exploit variation at plant location level to construct an instrument for a plant's "share VI" and thereby establish causality. Variation in which ports independent boats supply in a given period arises due to natural variation (in fish density and weather) and decisions made by their captains. We thus instrument a plant's "share VI" at the time of production with the number and share of independent suppliers concurrently supplying local plants belonging to *other* firms. This approach yields estimates that are very similar to the OLS estimates. While other mechanisms may also contribute to the association between a firm's organizational structure and output quality, the relationship is thus at least in

[4] The fair average quality versus prime classification is dichotomous and governed by a protein content (quality) ladder cut-off.

part due to a causal effect of the use of integrated suppliers on output quality.

We then investigate if firms in fact change their organizational structure to meet output quality objectives. We construct instruments for firm specific shocks to foreign demand for quality.[5] We use these to show that downstream manufacturers acquire more suppliers and thereby increase their "share VI", when faced with greater *relative* demand for high quality output.

To guide our investigation of *how* integration enables firms to produce higher quality output, we present a simple framework building on the seminal Baker *et al.* (2002) model, in which independent suppliers may devote effort to increasing the value of their assets (in our case, inputs produced) to alternative buyers. We assume that suppliers can take both quantity- and quality-increasing actions, and allow for two types of downstream firms: those focusing only on producing quantity, and those who (e.g. because they have a comparative advantage in producing high end goods) also put weight on the quality of their output. We take both input quantity and input quality to be observable but non-contractible.[6] The framework highlights that it may be that quantity-oriented firms can achieve the first-best via "relational outsourcing" contracts with independent suppliers, but that quality-oriented firms can do so only via "relational employment" contracts—i.e., by integrating.

In the final part of the paper, we show empirically that a supplier changes its behavior—taking actions to deliver inputs of higher quality—when it is acquired by the firm being supplied (and vice versa if sold). *A given supplier supplying a given plant* starts delivering inputs in smaller batches of higher quality (i.e., fresher) fish (but lower total quantities) when acquired by the plant's owner. The change in behavior when integrating with or separating from the downstream firm being supplied is greater during periods (i) when the firm is trying to produce high quality output, and (ii) when plankton scarcity tightens the supplier's trade-off between quantity- and quality-increasing actions. These changes in behavior explain part of the relationship between "share VI" and quality grade produced. We show that, in contrast, independent suppliers do not deliver inputs of higher quality if they become engaged in repeated interactions with the plant supplied. Our findings are thus consistent with the idea that vertical integration enables downstream firms to incentivize specific supplier behaviors that other organizational structures may not.[7] We also discuss how alternative models, such as those on "adaptation", may help explain some of our findings.[8]

In sum, this paper shows that Peruvian manufacturers produce products of higher quality when inputs are sourced internally because they have greater control over the behavior of integrated suppliers. The manufacturers are aware of and take advantage of this benefit of integration. We thus document an overlooked consequence of, and motivation for, vertical integration. Does the integration-quality relationship hold also outside of the context we study? In general, there is a robust relationship between countries' input-output structure and their level of contract enforcement (Boehm, 2016), and vertical integration is more common in developing countries (Acemoglu *et al.* , 2009; Macchiavello, 2011). Of course, if contracts are difficult to enforce then firms may choose to vertically integrate also for other reasons than to produce high quality

[5]Specifically, we instrument for the demand a firm faces at a given point in time by interacting its initial export destinations with importer countries' total imports at that later point in time. We follow many fruitful applications of such an approach in the trade literature, including Park *et al.* (2009); Brambilla *et al.* (2012); Bastos *et al.* (2016).

[6]The features of Peru's fishmeal manufacturing sector that lead us to make these assumptions are discussed in Section 2.

[7]If relational outsourcing contracts are used in the context studied, they likely address other firm needs (see e.g. Macchiavello & Miquel-Florensa, 2016). Note also that our results indicate that what non-integrated suppliers in the Peruvian fishmeal manufacturing industry lack is not the *knowledge* to produce high quality inputs, but rather the *incentives* to do so. We show, for example, that a given supplier produces high quality inputs only when supplying its owner firm, and not when owned by one firm but supplying another.

[8]See e.g. Williamson (1975, 1985); Tadelis (2002); Dessein & Santos (2006); Forbes & Lederman (2009, 2010); Baker *et al.* (2011); Gil *et al.* (2016); Barron *et al.* (2017).

output. However, in the concluding section of the paper we document a positive relationship between (a proxy for) the average quality of a given type of manufacturing product a country exports to the U.S. and the average degree of vertical integration among the exporters. While the relationship between organizational form and firm performance in general depends both on context and the relevant dimension of performance (see e.g. Kosová *et al.* , 2013), our findings thus appear to reflect an association between vertical integration and manufacturing output quality that is not unique to the Peruvian fishmeal industry.

Our study bridges and advances the literatures on organizational structure and quality upgrading. The body of empirical work on the causes and consequences of firms' choice of structure in developing countries, which began in earnest with Woodruff (2002), is small. Woodruff finds that vertical integration is less common in the Mexican footwear industry when non-contractible investment by retailers is important, as the property rights framework (Grossman & Hart, 1986; Hart & Moore, 1990) predicts (see also Natividad, 2014; Macchiavello & Miquel-Florensa, 2016).[9] What distinguishes our paper from existing studies in this literature is that the data and variation we exploit allow us to identify how and why vertical integration affects firm performance, and that we focus on a particular firm objective: producing high quality output.

The literature on the relationship between quality upgrading in firms and economic development is larger. It is now well-documented that producers of high quality goods use high quality inputs (Goldberg *et al.* , 2010; Kugler & Verhoogen, 2012; Manova & Zhang, 2012; Halpern *et al.* , 2015; Bastos *et al.* , 2016), more skilled workers (Verhoogen, 2008; Frías *et al.* , 2009; Brambilla *et al.* , 2012; Brambilla & Porto, 2016; Brambilla *et al.* , 2016), and export to richer destination countries (Hallak, 2006; Verhoogen, 2008; Manova & Zhang, 2012; Bastos *et al.* , 2016). Firms with such a profile tend on average to be bigger, more productive, and to be based in richer countries themselves (Schott, 2004; Hummels & Klenow, 2005; Baldwin & Harrigan, 2011; Johnson, 2012). Our contribution is to document how another dimension of production—a firm's organizational structure—matters for output quality, and that firms strategically change their organizational structure in response to changes in demand for high quality grade output.

While contracting challenges and quality objectives loom especially large for firms in developing countries, the integration-quality relationship we document appears to hold on average across countries and industries in export manufacturing. Gibbons (2005); Lafontaine & Slade (2007); Bresnahan & Levin (2012) provide excellent overviews of existing research on the boundaries of the firm.[10] Theories of organizational structure have been difficult to take to the data, and studies that identify causal *consequences* of vertical integration for firm performance are especially rare (see Forbes & Lederman (2010) for an exception[11]). Our contribution is two-fold. First, firms' organizational structure varies over time in the Peruvian fishmeal industry, and exogenous factors drive part of the variation in the share of plants' inputs coming from integrated suppliers. This means that we can compare the overall quality performance of *the same firm* under

[9] Macchiavello & Miquel-Florensa (2016)'s innovative study shows how supply assurance motives influence choice of organizational structure (and use of relational contracts) in the Costa Rican coffee industry by relating measures of ex post reneging temptations to ex ante choice of structure (see also Banerjee & Duflo, 2000; Macchiavello & Morjaria, 2015). We follow Natividad (2014) in studying vertical integration in the Peruvian fishmeal industry. He finds no difference between the quantities supplied by firms' integrated and non-integrated suppliers during an earlier regulatory system with industry-wide fishing quotas. (See Section 2 and Hansman *et al.* (2016) for details on the regulatory system in place before our study period, which led to a famous "Olympic race" for fish that appears to have overshadowed other forms of incentives and industry dynamics (Natividad (2014) does find a correlation between quantity supplied and integration status among the suppliers of one firm)). There is also a broader literature on business groups in developing countries (see e.g. Bertrand *et al.* (2008) and a summary of the literature in Khanna & Yafeh (2007)).

[10] There is also an influential literature studying the relationship between integration and international trade (see e.g. McLaren, 2000; Grossman & Helpman, 2002; Antràs, 2003; Nunn, 2007; Antràs & Staiger, 2012; Irarrazabal *et al.* , 2013; Antràs, 2014, 2016).

[11] Like us, Forbes & Lederman (2010) are able to exploit exogenous drivers of whether integrated or independent suppliers are used. They show that there are fewer delays and cancellations on routes airlines self-manage. Other important contributions include Novak & Stern (2008); Gil (2009); Kosová *et al.* (2013).

different organizational structures and *the same plant* when supplied by integrated versus independent suppliers, allowing us to rule out firm and firm×time period level confounds. It also means that we can separate the effect of a change in plants' source of supply from that of correlated changes that induce managers to integrate or sell their suppliers.[12] Second, we are not aware of previous studies of the role vertical integration plays when downstream sectors are segmented and some firms aim to produce high quality output while others do not.[13] In such a setting, the concept of firm performance and supplier incentives differ.

We in turn show that vertical integration, by facilitating the production of a particular type of goods, motivate firms to change their organizational structure when the composition of demand shifts, linking our paper with a larger existing literature on the *causes* of organizational structure. Baker & Hubbard (2003) find, for example, that on-board computers' incentive-improving features push U.S. trucking companies towards using employed drivers, while their resource-allocation-improving features instead increase the use of independent drivers (see also Hart *et al.* (1997); Forbes & Lederman (2009); Baker & Hubbard (2004)). We focus on a potential incentive to integrate—demand for high quality grade goods—that has not been studied before. Like Baker & Hubbard (2003, 2004), we take advantage of *time variation*—arising from fluctuations in importing countries' demand—to estimate how firms' integration and sourcing decisions change in response.[14] We are not aware of any existing work relating between- and within-firm supply and sales transactions over time to a dynamic model of organizational structure, as we do in this paper.

With estimates of the benefits and drawbacks (and composition-of-demand-responsiveness) of each organizational structure in hand[15], we follow, among others, Mullainathan & Sharfstein (2001); Baker & Hubbard (2003, 2004); Macchiavello & Miquel-Florensa (2016) in relating these to measures of supplier behavior. However, we identify *changes* in a supplier's behavior—and "adaptation"—that occur when the supplier integrates with or separates from the plant being supplied, isolating the effect of integration status from that of other correlated supplier-plant characteristics.[16]

The rest of the paper is organized as follows. In Section 2 we provide context background, and in Section 3 we lay out the data we use. In Section 4 we explore the association between output quality and vertical integration, and in Section 5 how firms' integration choices change with demand for quality. In Section 6 we investigate *why* organizational structure and quality may be related. Section 7 concludes.

[12]Of course, Peruvian fishmeal manufacturing firms do have some control over which particular plants their integrated suppliers deliver to on a given day. Studying the endogenous component of the match between suppliers and plants at a given point in time is beyond the scope of this paper: here we instead exploit the exogenous component for identification.

[13]In settings where product differentiation is multi-dimensional or prices are unobserved, such an analysis would be difficult. Our focus on a vertically differentiated but horizontally homogeneous product is inspired by influential earlier papers testing market power theories of integration in sectors producing homogeneous products (Syverson, 2004; Hortacsu & Syverson, 2007; Foster *et al.* , 2008).

[14]Forbes & Lederman (2009) take advantage of inherently exogenous, cross-sectional variation—in weather—to instrument for airlines' decision to integrate a particular route. Baker & Hubbard (2003, 2004) infer the firms' objective from the type of job contracted over. In our setting, firm outcomes are directly observed. Our demand results resonate with the findings of Alfaro *et al.* (2016) comparing industries across countries and time. They show that higher prices for homogeneous final products allow firms to overcome the costs of integrating (see also Legros & Newman, 2013).

[15]We can assess the extent to which the benefits of integration can also be achieved through repeated interactions because we observe some supplier-firm pairs transacting both as independent and integrated entities, and others transacting as independent entities and when engaged in repeated transactions. See e.g. Macaulay (1963); Klein & Leffer (1981); McMillan & Woodruff (1999); Banerjee & Duflo (2000); Johnson *et al.* (2001); MacLeod (2007); Gil & Marion (2013); Macchiavello & Morjaria (2015) on relational contracts.

[16]Baker & Hubbard (2003, 2004) helped spark an empirical literature relating supplier multitasking to organizational structure. In their context, downstream firms want suppliers to multitask on some jobs, but not on others. In our case, some downstream firms want suppliers to take particular actions, but doing so may make the suppliers' product less desirable to alternative buyers. Like Mullainathan & Sharfstein (2001), we directly observe supplier behavior. We also provide a new form of evidence on how supplier "adaptation" depends on organizational structure (Williamson, 1975, 1985; Tadelis, 2002; Dessein & Santos, 2006; Forbes & Lederman, 2009, 2010; Baker *et al.* , 2011; Barron *et al.* , 2017) by documenting how the way in which suppliers adjust their quality-related behavior to variation in production conditions and plant needs depends on whether they are integrated with the plant supplied. Atalay *et al.* (2014) also exploit changes in integration within supplier-firm pairs, but focus on the transfer of intangible knowledge.

2 Background on Peru's Fishmeal Manufacturing Sector

2.1 Technology and product differentiation

Peru is the world largest exporter of fishmeal, making up around 30 percent of the world's exports. The anchovy fishery that supplies its fishmeal manufacturing plants account for approximately 10 percent of global fish capture (Paredes & Gutierrez, 2008). During our data period, around 95 percent of Peru's total fishmeal production was exported. The three largest buyers are China, Germany, and Japan, but many other countries also import Peruvian fishmeal (see Appendix Table A1). The product is primarily used as feed for agriculture and aquaculture.

Peru allows anchovy fishing for fishmeal production during two seasons each year.[17] The fish is processed as soon as possible after being offloaded as fishmeal is more valuable when made from fresh fish. Freshness at the time of delivery depends on several choices made by the boat's captain before and during a trip, such as the amount of ice brought on board, how tightly fish is packed, and the time spent in between a catch and delivery to a plant.

Because of the need for fresh fish, fishmeal plants operate only during the fishing seasons. In theory fishmeal can be stored for up to six or even 12 months, but we find that almost all is sold before the next production season begins, as shown in Appendix Figure A1 and discussed below.

Boats offload fish at a plant's docking station. The fish is then transported into the plant, normally via a conveyor belt. Inside the plant, the fish is weighed, cleaned, and then converted into fishmeal. Plants can use two different technologies to turn fish into fishmeal: steam drying (hereinafter "High technology"), and exposing the fish directly to heat (hereinafter "Low technology"). The High technology preserves the protein content of the fish through the production process better. As seen in Appendix Figure A2, firms and plants that use the High technology produce higher average quality fishmeal, though plant technology is far from the only factor influencing output quality, as reflected in the standard deviations shown (we discuss the data used in Section 3).

The exact quality grade of a batch of fishmeal is denoted by its protein content, which in Peru typically ranges from 63 to 68 percent. In addition, batches with protein content above a given level are labeled "prime" quality: plants report, for example, their production of prime and "fair average" (below prime) quality fishmeal to regulatory authorities each month. Price differentials across transactions for Peruvian fishmeal of a given quality grade in a given time period are negligible.

2.2 Sector profile and firms' organizational structure

Around 22 towns along the coast of Peru have a port that is suitable for large fishing boats; all fishmeal plants are located in and around these ports. Table 1 shows summary statistics on the fishmeal sector for our sample period. In 2009 there were 89 active fishmeal plants. They were owned by 37 firms, but the seven largest firms account for approximately 78 percent of total production.

[17] Our period of analysis is 2009 to 2015, or the first 11 fishing and fishmeal production seasons after the introduction of "individual, transferable quotas" (ITQs) in the Peruvian anchovy fishery. Before ITQs, the sector operated under a shared, aggregate quota—or "race for the resource"—system wherein there was little scope for incentives that depend on the organizational structure of the production chain or other features of the economic environment to influence a boat's behavior (see e.g. Hansman *et al.* , 2016), other than possibly how fast the boat would "race". Under the ITQ system, Peru's anchovy fishery is similar in many dimensions to other primary sectors that supply downstream factories, including the natural resources from which raw materials are extracted being privately owned.

There are on average 812 active boats per fishing season, and significant heterogeneity in boat characteristics such as storage capacity, engine power, and average quantity caught per trip. Fishing trips last 21 hours (s.d. = 10 hours) and boats travel 76 kilometers to the port of delivery (s.d. = 46 kilometers) on average, underscoring the effort necessary to find and capture fish. Note that changes in installed technology are rare both for boats and plants during our data period.

There is heterogeneity also in processing capacity, technology, and the share of production that is of high quality grade across plants. Monthly average production is 3116 metric tons (s.d. = 3266 tons). Firms differ considerably in their average number of export transactions per season, and the size and value of their shipments. As seen in Appendix Figure A3, firm size correlates positively with average quality grade produced, consistent with Melitz (2003) style models in which unobserved firm heterogeneity governs firms' targeted output quality, other production choices, and size, and changes in demand- or supply-side factors can lead to changes in the targeted output quality (see, among others, Verhoogen, 2008; Khandelwal, 2010; Baldwin & Harrigan, 2011; Johnson, 2012; Kugler & Verhoogen, 2012). Such a perspective also appears consistent with a bird's-eye view of the evolution of the Peruvian fishmeal sector during our data period.

During the period we study, the Peruvian fishmeal industry was characterized by short-run fluctuations in (i) the composition of demand, (ii) firms' organizational structure, and (iii) average quality grade produced—the focus of our analysis—around weakly positive longer-term trends in industry-wide average quality level produced and degree of vertical integration. Regulations allow only steel boats to be owned by fishmeal firms. Firms can generally vary the amount of input they obtain from integrated suppliers in a given production season only by acquiring or selling suppliers: a firm's integrated suppliers are essentially always used to capacity—the boat's full fishing quota is caught[18]—over the course of a season. On average, 28 percent of the boats that are active in a given season are owned by a fishmeal firm, as seen in Table 1. Downstream ownership of boats slowly increased during the last decade.[19] This slow growth in ownership of suppliers occured in parallel with Peruvian fishmeal firms (also slowly) increasing the share of their output that is of high quality grade.

A firm's total amount of input used, and therefore its input mix, depends both on its ownership of suppliers and its purchases from independent suppliers. On average, firms increased their "share VI"—the share of inputs they obtain from integrated suppliers—by 2.9 percent from season to season during our data period. As shown in Appendix Table A2, approximately 77 percent of this growth came solely from increasing the amount of input coming from integrated suppliers, and the rest from lower total input purchases.

A *plant's* input mix at a given point in time depends mostly on the organizational structure of the firm the plant belongs to, but also on the extent to which firm managers direct integrated suppliers to deliver to the plant, and the presence of independent suppliers near the plant. The latter varies considerably over time, and depends on variation in weather, fish density, and independent captains' decisions. Plants purchase inputs both from independent suppliers with whom they interact frequently, and from independent suppliers they rarely interact with.

[18]This is both because independent suppliers must be paid for the inputs they supply and because a firm not using its entire fishing quota would reduce its quota in future production seasons.

[19]See Appendix Figure A4. While the long-term trend in downstream ownership of boats has been positive, we also observe some sales of boats from fishmeal firms to independent co-ops or captains in the data. There was a bigger jump in downstream firms acquiring boats with the introduction of ITQs. As discussed above, we focus on the post-ITQ period. Steel boats that are not owned by fishmeal firms are generally owned by co-ops ("armadores"), while wooden boats are generally owned by individuals or families.

2.3 Contracting and supplier incentives

There is no centralized spot market for fish purchases: plants are spread out along the coast, in part because the fish move around. Where an independent boat makes a catch constrains the set of ports it can deliver to. Because of the importance of fish freshness, when returning from fishing, independent captains begin contacting plants over the radio on their way to a port. As noted in the introduction, the complex multitasking necessary to produce high quality fish, the difficulty of contracting over quality, and the presence of plants with heterogenous demands for quality mean that a spot market may not be the natural organizational structure for the industry as a whole. We explore these issues more in Section 6.

Fresher anchovies yield fishmeal with higher protein content on average. Though fish quality is not measurable at the time of delivery, informative signals exist: for example, the smell of the fish, and real-time information on boats' location made publicly available by the regulatory authories.[20] On the other hand, it is difficult to contract over fish quality. Many of the signals available are complicated to quantify and difficult to enforce, particularly given the limited capacity of Peru's courts and other law enforcement institutions. Furthermore, the quality of the final good—fishmeal—is only directly observed by the downstream firm itself, whose own actions also influence output quality. Additionally, the production technology makes it difficult to avoid using fish from multiple suppliers when making a given batch of fishmeal.

The size of a boat's catch is observable to the purchasing plant at the time of delivery, but nevertheless also difficult to contract on. Firms' desired quantity of inputs depends on many factors that are hard to verify ex post (e.g. fishing conditions, the timing of deliveries from other suppliers, variation in demand, etc) and costly to specify ex ante (see also Macchiavello & Miquel-Florensa, 2016).

We interviewed fishmeal industry associations, a major company's Chief Operating Officer, and others in the sector to gain a qualitative understanding of the characteristics of the contracts used and the incentives suppliers face. The interviewees reported that captains of boats owned by fishmeal firms generally are paid a fixed wage, in some cases with a bonus tied to some measure of performance.[21] They also reported that payments to independent suppliers generally are agreed upon case by case, but in most cases are calculated simply as quantity multiplied by a going price. We use internal data on payments to suppliers from a large firm to confirm this. These indicate that at a given point in time independent suppliers are paid a price per metric ton of fish delivered that is essentially fixed: port$\times$date fixed effects explain 99 percent of the price variation across transactions. To the extent that repeated interactions (or other alternatives to integration) are used in the Peruvian fishmeal industry to incentivize specific supplier behaviors, such arrangements are thus of a nature that does not require paying certain suppliers more than others.

3 Data and Empirical Approach

3.1 Data

The primary datasets we use are the following:

[20] As discussed in Section 3 below, the fishing boats transmit GPS signals to the regulatory authorities in real-time. The map that displays the last recorded location of each boat is periodically updated and is publicly accessible.

[21] The firm that shared its data with us reported that it pays its captains and crews fixed wages. The fishmeal industry assocations reported that payment schemes vary across firms; that some pay bonuses tied to measures of performance; but that these are on top of a fixed wage and usually small.

Plant production. We use administrative data on all plants' production from Peru's Ministry of Production, which regulates the fishmeal industry. Plants are required to submit information on how much prime (high quality) and fair average (low quality) type fishmeal they produce every month. Quality grade is thus directly reported in the plant production data, and subject to auditing by government inspectors. As discussed in Sub-section 2.1, the distinction between prime and fair average quality fishmeal as reported by plants is based on a cut-off on the protein content ladder.

Plant registry. We link the production data with an administrative plant registry that contains information at the monthly level on each plant's technological production capacity and which firm owns the plant.[22] We also use this registry to link the production data to export data. We can do so for almost all firms.[23]

Export transactions. We use detailed data on the universe of fishmeal exports at the transaction level from Peru's customs authority. We observe the date of the transaction, the export port of transaction, the destination country, the weight of the fishmeal, the value of the transaction, and the exporting firm (though not the specific plant that made the fishmeal).

While we do not directly observe the exact protein content of each export shipment, we can approximate this precise quality grade measure unusually well. This is because we observe quality grade-specific fishmeal prices in granular (week×export port×protein content level) data recorded by a fishmeal consulting company. Taking advantage of the vertically differentiated but horizontally homogeneous nature of the product, we infer the protein content of a firm's exports at each point in time by comparing the unit values of export shipments to this price data. The inferred protein content of a firm's exports at a point in time is highly correlated with the "high quality share of production" directly observed for the firm's plants in production data.[24] Firms do not have the market power to charge mark-ups: as noted above, port×date fixed effects explain 99 percent of the within quality grade price variation across transactions. Our inferrence procedure can thus be used to accurately measure each shipment's quality grade.

We also report results using export unit prices as the dependent variable. Unit prices are highly correlated with protein content and important firm outcomes in their own right.

Internal data from a large firm. One of the largest fishmeal firms in Peru shared its internal records on sales with us. The firm has been operating for more than a decade, and owns many plants throughout the coast. The sales records are detailed and include information on the shipment's type of packing, its free-on-board value, the price per metric ton, the buyer, destination country, date of the contract, and the terms. Most importantly for our purposes, the sales records include information on the specific plant that produced a given shipment of fishmeal.

Supply transactions. The Ministry of Production records all transactions between the fishmeal plants and their suppliers of raw materials, i.e. fishing boats. Information on the date of the transaction, the boat, the plant, and the amount of fish involved (though not the price), is included.

Boat registry. We merge the supply transactions data with an administrative boat registry that provides information on a boat's owner, the material the boat is made of, its storage capacity and engine power, and whether it has a cooling system installed.[25]

[22]For firms, the data contain information on the number of metric tons that can be produced per hour with respectively the installed Low and High technology, while for plants we observe an indicator for whether the plant has any of each type of technology installed. As very few firms in our sample only have the Low technology, we define a High technology firm as one for which the High technology share of total processing capacity is higher than the median (0.67).

[23]The smallest firms use intermediaries to export. We cannot link intermediated exports to a specific firm's production.

[24]Unit values are uncorrelated with the size of the shipment, indicating that fishmeal firms do not offer bulk discounts.

[25]Information on engine power is only available for 2004-2006 so we do not observe changes from one year to another during our

Boat GPS data. Peruvian fishing boats that supply fishmeal plants are required to have a GPS tracking system installed, and to continuously transmit their GPS signal to the Ministry of Production while at sea. The ministry stores the transmitted information—the boat's ID, latitude, longitude, speed, and direction—each hour on average, and shared the resulting dataset with us.

Since we do not directly observe when and where a boat has its nets out, we construct an algorithm to infer fishing location and -time. The algorithm exploits the fact that a boat's speed is lower when searching for fish or actively fishing than when traveling back to port.[26]

It is important to note that only about half of the observations in the Supply transactions dataset can be matched to a GPS recording, and the missing GPS observations are not "missing at random". Some boat owners, for example, disappear from the GPS data for a complete calendar year. However, such missingness is unlikely to be of concern for within-boat analysis, the level at which we use the GPS data.

In addition to these primary datasets, we also use the two following sources:

International trade flows. To construct our instruments for firm specific shocks to foreign demand for fishmeal quality—specifically, to measure the amount of fishmeal that Peru and other countries export and import each year—we use BACI data.[27]

Phytoplankton data. We use NASA chlorophyll concentration data from satellite images to predict fish abundance. This data allows scientists to measure how much phytoplankton is growing in the ocean by observing the color of the light reflected off the water. The data is available for each date and each 0.1°-latitude×0.1°-longitude (roughly 10 kilometer×10 kilometer) grid-cell.[28]

3.2 Empirical approach

As discussed in the introduction, we aim to test whether vertical integration is *effective* as a strategy for producing high quality output and whether firms *use* integration as a strategy for producing high quality output. We generally expect profit-maximizing firms to make use of strategies that are effective and hence for firm strategies to be either both effective and used or neither. Nevertheless, the fact that a change in organizational structure may originate in a change in the composition of demand may confound (conjectured) evidence supporting a direct effect of organizational structure on output quality (and vice versa), as illustrated in Figure 1.[29] Separate identification is thus needed to test the *effectiveness* ($X \rightarrow Y$) and *use* ($X \leftarrow Y$) component of the overall integration-quality relationship we hypothesize.

We begin by estimating how vertical integration affects output quality (arrow (2) in Figure 1), in Section 4. To do so we take advantage of changes over time in firms' organizational structure and exploit leave-

analysis period. However, changes in engine power are very rare from 2004 to 2006 so we treat this characteristic as fixed.

[26]Specifically, we follow Natividad (2014) and assume that a boat has its nets out if speed is below 2.9 kilometers/hour. The industry association IFFO confirmed to us that the method should provide fairly accurate results. We have also used two alternative algorithms for inferring fishing location and -time; these yield similar results.

[27]BACI is a consolidated version of COMTRADE (with less missingness) and provides the quantity of goods of each HS6 code exported from one country to another in a given year (Gaulier & Zignago, 2010). For 2015 we use COMTRADE because 2015 BACI data is not yet available. BACI data is only available at the year level while our measures of quality produced are at the season level, with some seasons spanning two years. We thus match a production season to the year in the BACI data that spans most of the season.

[28]Phytoplankton contain a photosynthetic pigment called chlorophyll that lends them a greenish color. In the rest of this paper, we use the term "plankton concentration" when referring to chlorophyll concentration. The data is no longer available at the date level on the NASA website (only at the week or month level), but was still available in late 2015 when we scraped the data. See http://neo.sci.gsfc.nasa.gov/view.php?datasetId=MY1DMM_CHLORA. Because some data points are missing, we interpolate the missing data by taking the average of date and geographical interpolations.

[29]Suppose e.g. we show that a shock to demand for high quality output induces firms to vertically integrate ($X \leftarrow Y$). If this is simply because such a demand shock loosens credit constraints, then this may also explain a correlation between vertical integration and output quality that is conjectured to arise because $X \rightarrow Y$ (if e.g. access to credit allows firms to also upgrade their technology).

firm-out variation in the presence of independent suppliers supplying a cluster of plants to instrument for a plant's input mix at a given point in time. In Section 5, we estimate how relative demand for high quality output affects firms' choice of organizational structure (arrow (1) in Figure 1) by exploiting firm specific foreign demand shocks. Finally, in Section 6, we study the change in a supplier's behavior observed when the supplier integrates with or separates from the plant being supplied—and how the change in behavior depends on the opportunity cost of and downstream need for quality-increasing supplier behavior—to understand *why* organizational structure and output quality may be related.

4 Vertical Integration and Output Quality

4.1 Estimating how vertical integration affects output quality

In this section, we estimate regressions of the form:

$$\text{Quality}_{it} = \alpha + \beta_1 \text{VI}_{it} + \beta_2 \text{HighTech}_{it} + \gamma_i + \delta_t + \varepsilon_{it} \tag{1}$$

where Quality_{it} is a measure of the quality of the output produced by firm or plant i during production season or month t. As discussed in Section 3, at plant level, we measure output quality as the share of fishmeal produced that is of "prime" quality, while at the firm level we measure output quality using protein content and log export unit prices. The latter two measures are averaged across specific export transactions, weighting by quantity. (For the firm that provided internal data, we can use these two measures also at the plant level). The two firm level quality measures are complementary. Unit prices—the measure of output quality typically used in the existing literature—are important outcomes in and of themselves, but could partially reflect mark-ups and/or within-season fluctuations in the world price of fishmeal. Protein content instead provides a granular measure of output quality itself. The share of fishmeal produced that is of "prime" quality represents a *direct* measure of output quality whose interpretation requires no assumptions.

Our interest is in β_1, which measures the relationship between output quality and VI. The type of technology the firm or plant uses to convert fish into fishmeal is an important determinant of output quality (see Appendix Figure A2), and one that could plausibly correlate with VI (Acemoglu *et al.* , 2007, 2010). We thus control for installed HighTech_{it}, i.e., steam drying (High) technology.[30] As we include production season or month and firm or plant fixed effects, we estimate within-time period changes in output quality for those firms or plants that see a *change* in VI within a given season or month, relative to other firms/plants that do not see a change in VI at the same point in time. Finally, ε_{it} is a heteroskedasticity robust error term. We cluster the standard errors at the firm level.[31]

A possible concern when matching sales transactions to input transactions is that fishmeal can be stored for several months so that firms might attempt to strategically time their export transactions based on time variation in the prevailing prices. In practice inventories are small—between +10 and -10 percent of total season production—as seen in Appendix Figure A1.[32] This is likely because many contracts are entered into

[30] As discussed in Section 3, at the firm level, HighTech_{it} is equal to the share of installed capacity that is of the high type, while at the plant level, where we observe whether any high technology is installed, HighTech_{it} is instead a dummy variable.

[31] Clustering the standard errors at firm level is not possible in the regressions where we used internal data from one firm.

[32] Firms ramp up exporting towards the end of the production season, and have typically shipped all fishmeal before the next season begins. Figure A2 shows the density of inventories defined as the difference between seasonal production and exports (during the production season and the months right after the production season) divided by total production (over the production season). As the

before the production season starts (which helps the fishmeal manufacturers and their foreign buyers reduce demand/supply uncertainty), and because firms' ability to strategically "time" their sales is in actuality limited. A related concern is that firms that are about to end operations and close down might sell off their fishmeal, in which case a lower unit price might not reflect lower quality but rather a "going-out-of-business" discount. To deal with this possibility, we exclude from our sample data from any firm×season observations that correspond to a firm's last season to produce and export fishmeal, but the results are robust to including these observations.

In the next two sub-sections, we document a robust relationship between vertical integration and average quality grade produced. We show that the relationship holds for each of the various ways we measure quality; when we measure VI within firms across time as the number of suppliers owned or as the share of supply coming from integrated suppliers ("share VI"); and when we measure VI within *plants* over time as share VI. We then discuss the type of story that could explain this collection of evidence in the absence of a causal effect of vertical integration on output quality, and show that we find the same relationship when we construct an instrument for share VI that directly addresses the remaining potential confounds.

4.2 Vertical integration and output quality at firm level

We begin by directly exploring our primary object of interest: the relationship between a firm's organizational structure and the quality grade of its output. In Panel A of Table 2 we see that owning one more supplier is associated with the fishmeal exported having a protein content that is 0.021 percentage points higher and commanding a 0.2 percent higher unit price. (We discuss the magnitude of these estimates in Section 5). As illustrated in Figure 1, we hypothesize that this relationship originates, at least in part, in the composition of a firm's demand: i.e., that firms acquire suppliers when they face high demand for high quality grade fishmeal because doing so facilitates the production of high quality output. Of course, in and of themselves, the results in Panel A are also consistent with an alternative scenario in which demand or other underlying factors simultaneously affect a firm's organizational structure and output quality, without the two being directly related.

In Panel B of Table 2 we show that, rather than ownership of suppliers per se, what matters for output quality is *the share of a firm's supplies coming from integrated suppliers at the time of production*. The results imply that fishmeal a firm were to produce with inputs coming entirely from integrated suppliers would have a 1.3 percentage point higher protein content than fishmeal produced by the same firm with inputs from independent suppliers. Similarly, the results imply that fishmeal produced with inputs from integrated suppliers would command 9 percent higher prices. This price differential is roughly equal to the difference between the average unit price of the lowest quality category and highest quality category fishmeal as defined by a five-step quality ladder used by industry associations that report average prices.

As discussed in the background section, firms generally use their integrated suppliers to capacity over the course of a season. It is thus not surprising that we see a corresponding change in a firm's input mix when the firm acquires or sells a supplier. "Share VI", however, accounts also for suppliers' size. More importantly, the results in Panel B help rule out perhaps the most plausible alternative explanation of the relationship documented in Panel A, namely that firm level shocks—for example to demand or productivity—that affect output quality independently also enable or incentivize a firm to acquire suppliers. The results

graph illustrates, for the vast majority of observations in our sample, inventories are between +10 and -10 percent of total production.

in Panel B do leave open the possibility that the relationship between output quality and concurrent *use* of integrated suppliers at firm level is due to shocks or changes in firm strategy that affect both. It is arguably less clear how this would occur in the absense of a direct relationship between use of integrated suppliers and output quality, but nevertheless possible.

We then show that it is the integrated-versus-independent status of the boats supplying a fishmeal firm at the time of production itself, rather than other correlated observable supplier and manufacturer characteristics, that matters for output quality. We repeat the regressions in Panel C of Table 2, but now include a series of additional controls. Controlling for the share of inputs coming from steel boats; high capacity boats; and boats with a cooling system (separately or jointly) leaves the magnitude and significance of the coefficient on share of inputs coming from VI suppliers essentially unchanged.[33]

In columns (2) and (4) of Panel C of Table 2 we add a control for the firm's share of total industry production. This has little impact on the estimated VI supply coefficient. This result provides further evidence against a story in which unobservable shocks induce firms to simultaneously acquire suppliers and increase output quality, without the former directly affecting the latter (as in, for example, Kugler & Verhoogen (2012)). The finding also suggests that a "foreclosure" story in which buying suppliers helps downstream firms increase their mark-ups by excluding competitors from the market cannot explain our results (see Ordover *et al.* , 1990; Hortacsu & Syverson, 2007), consistent with the fact that price variation within quality grade is negligible.

The advantage of analyzing the relationship between vertical integration and output quality at the firm level is that organizational structure as conventionally defined is a firm level feature. In the next sub-section we analyze the relationship between output quality and a measure of vertical integration defined at the *plant* level, for three reasons. First, a plant level analysis allows us to rule out any potential confounds that operate at the firm×time period level. Second, at plant level we directly observe output quality. Finally, the fact that each plant is located at a particular point along the coast means that we can exploit exogenous variation in "share VI" that arises at location×month level to instrument for the share of a plant's inputs that come from integrated suppliers in a given month. In this sub-section we have seen that the relationship between a *firm's* organizational structure and the quality of its output appears to be driven by the share of its inputs coming from integrated suppliers at the time of production. Since the same variable can be constructed at plant level, we can use the plant level analysis to understand the relationship between a firm's organizational structure and output quality in more detail.

4.3 Vertical integration and output quality at plant level

We find the same relationship between a plant's output quality and the share of its inputs coming from integrated suppliers across time as we do across firms across time. In Panel A of Table 3, we use the directly observed, dichotomous measure of output quality discussed in Section 3: total production of high quality type and low quality type fishmeal. This plant level quality measure is available for all 89 plants in the full sample and reported at the month level.[34] The results in columns 1 and 2 imply that the share of a plant's

[33] We define "high capacity" as greater than the 75th percentile. Note that two of the supplier characteristics variables included—Share of inputs from high capacity boats and Share of inputs from boats with cooling system—are significantly correlated with output quality *in the cross-section* of firms. One reason why the coefficients on these characteristics are not significant is that we observe little change in these boat characteristics over time.

[34] Note that running the regressions in Sub-section 4.2 at month level would require an assumption about how firms "manage their inventories" (for example, first-in-first-out versus first-in-last-out). We instead match export shipments to firms' ownership of suppliers

output that is of the high quality type would be seven percent higher if the plant were to obtain all of its input from VI suppliers, relative to when obtaining all of its input from independent suppliers.

We also find the same integration-quality pattern across different plants *within the same firm* across time. In Panel B of Table 3, we repeat the analysis from Panel B of Table 2—that is, we use protein content as our measure of quality—but now at the plant rather than the firm level. This is possible for the sample of plants belonging to the fishmeal firm that shared data with us, enabling us to link the firm's export transactions with the specific plant that produced the fishmeal. We include plant fixed effects and thus focus on changes in share VI within a production season and within a given plant. The magnitude and significance of the estimates are very similar to those in Panel B of Table 2.

As discussed above, organizational structure can co-vary with output quality without necessarily reflecting a causal relationship. The existing literature points to several ways in which this can occur, e.g. an increase in demand for high quality output loosening credit constraints that otherwise prevent a firm from acquiring suppliers. Such stories generally operate at firm or firm×time period level, however. We have documented a positive, statistically significant, and quantitatively consistent association between share VI and export shipments' average quality grade at (i) firm and (ii) plant level across production seasons, and (iii) between share VI and a directly observed output quality measure at plant×month level. Our findings are thus difficult to reconcile with explanations that do not operate at plant (sub-firm)×month level. The remaining potential alternative to organizational structure directly affecting output quality is that plant specific shocks, for example to productivity[35], occur and *independently* affect the quality of a plant's output and firm managers' desire or ability to increase the share of the plant's supply coming from integrated suppliers. If so, managers may be able to respond through a lever that is less relevant a firm×season level: which particular plant(s) the firm's integrated suppliers deliver to in a given week or month. Beyond the constraints due to natural variation in weather and fish density and where boats are located before embarking on a specific fishing trip, a firm generally controls where its integrated boats travel to in a given period.

To address this final concern, we construct an instrument for a plant's de facto organizational structure at a particular point in time. Which ports independent boats and integrated boats owned by other firms supply in a given period is generally outside of the control of the firm in question. We thus instrument the share of a plant's supplies coming from integrated suppliers with the number of independent boats supplying *other* firms in the port at the time of production, as well as the same number divided by the total number of boats supplying other firms in the port at the time of production. This instrument has a strong first stage because the number of independent boats supplying other plants in the port is highly correlated with the number of independent boats supplying the plant in question during the same period. On the other hand, the composition of other plants' supplies has no direct impact on the quality of the fishmeal produced by the plant in question, implying that the exclusion restriction holds.[36]

Results from the IV specification are presented in columns 3 and 4 of panels A and B in Table 3. In both panels, the IV estimates are of the same sign and general magnitude as the corresponding OLS estimates,

and supply transactions at season level, avoiding the need to make such assumptions.

[35] Another example of a shock that may affect different plants within a firm differently is El Niño, which hit Peru in late 2009.

[36] There are three potential concerns with our instrument. First, a plant's use of independent suppliers might itself affect the "share VI" of other plants in the port due to an "adding up" constraint. Such a story would imply a positive sign on the coefficient on the instrument in the first stage: we find a negative sign. Second, high fish density might simultaneously enable plants to produce higher quality fishmeal (as we show in Section 6) and attract independent fishing boats. Such a story would also imply the opposite sign of what we find in the first stage. Finally, it is conceivable that independent suppliers are aware of which plants are aiming to produce high quality fishmeal at a particular point in time and try to avoid the ports where many such plants are present. While difficult to formally rule out, such stories essentially pre-suppose the effect of share VI on output quality we hypothesize to be true.

only slightly bigger. Three of the four IV estimates are also statistically significant. We have thus established a causal effect of the share of a plant's supplies coming from integrated suppliers at the time of production on output quality.

In this section we began by documenting a positive association between the number of suppliers owned by a firm and its average output quality, and that this association is driven by the share of the firm's supplies coming from integrated suppliers at the time of production ("share VI"). We then showed that the same relationship holds at plant level—where output quality is directly observed—allowing us to rule out confounds due to firm and firm×time period level shocks and how quality is measured. Finally, we constructed an instrument for share VI and showed that its positive relationship with the quality of a plant's output is causal. We conclude that, while other mechanisms may also contribute to the association between a firm's organizational structure and output quality we established in Table 2, the relationship is at least in part due to a causal effect of the use of integrated suppliers on output quality.

5 Demand for Output Quality and Vertical Integration

5.1 Estimating how demand for output quality affects vertical integration

If an integrated organizational structure helps downstream firms source high quality inputs more efficiently, then profit maximizing manufacturers should make greater use of integrated suppliers when demand for high quality grade products is high. Empirical support for this prediction would, in addition to demonstrating that manufacturers in Peru are aware of and able to act on the particular path to export success we study, represent evidence of an overlooked determinant of firms' organizational structure.

To test how acquisitions and sales of suppliers and firms' input mix respond to the composition of final demand, we use quality-differentiated demand shocks to instrument for the observed quality grade of a firm's exports at a given point in time. Our approach relies on two important facts about the Peruvian fishmeal sector. First, firms export different quality grades to different destinations. This is apparent in the export transactions data, where some destination countries (e.g. Chile and Japan) consistently buy higher unit price and protein content fishmeal than other countries.[37] It is also clear in the sales records of the large firm that shared its data with us, where the quality column for exports to some destination countries is simply filled in with the name of the country (e.g. "Thailand quality"). An increase in demand from high quality importers should thus increase the quality content of Peruvian fishmeal exports.

The second important fact about the Peruvian fishmeal sector is that the timing of sales contracts relative to production is typically such that a firm can change its supply strategy in a given production season in response to high or low demand from particular importer countries. An industry association informed us that almost all contracts for a given season's production are negotiated either before the season starts, or early in the season.

To construct our demand shocks, we follow an approach similar to Bastos *et al.* (2016) (see also Park *et al.* (2009); Brambilla *et al.* (2012)). In the second stage, we estimate how acquisitions/sales of suppliers and

[37] See Appendix Table A1 for a list of the main importers of Peruvian fishmeal and the average quality imported. Some of the countries that import comparatively high quality grades of fishmeal are rich—for example Canada, Chile, and Japan—while others are middle-income. Note that, as for humans, quantity and quality of feed (the latter here defined by protein content) are highly imperfect substitutes for farm animals and farmed fish.

firms' input mix respond to the quality grade produced:

$$\text{VI}_{it} = \alpha + \beta_1 \text{Quality}_{it} + \gamma_i + \delta_t + \varepsilon_{it} \tag{2}$$

We control for firm and production season fixed effects and cluster the standard errors at firm level as in Section 4. In the first stage, quality grade produced is instrumented by demand shocks from specific destinations as follows:

$$\text{Quality}_{it} = \gamma_i + \delta_t + \sum_j \beta_j \; (\text{I}^j_{i2008} \; S^j_{-P,t}) + \varepsilon_{it} \tag{3}$$

where j is an export destination country, and $\text{I}^j_{i2008} \; S^j_{-P,t}$ are our excluded instruments. I^j_{i2008} is a dummy variable equal to one if firm i exported to destination j in 2008, the year prior to our analysis period. $S^j_{-P,t}$ is the leave-Peru-out share of global fishmeal exports going to country j in season t. $S^j_{-P,t}$ is therefore a proxy for the relative demand coming from destination j at a given point in time. Changes in j's demand should matter more for firms that previously exported to j, which we capture in the interaction between $S^j_{-P,t}$ and I^j_{i2008}.

5.2 Variation in foreign demand for quality and vertical integration

The OLS and the second stage IV results of interest are reported in Table 4. We find that firms respond to positive shocks to demand for high quality fishmeal by acquiring more suppliers and by sourcing a higher share of their inputs from integrated suppliers.[38] The estimates in Panel B indicate that an increase in the average protein content level a firm's output needs to reach in order to meet its foreign buyers' demand of one percentage point—or 23 percent of the observed range for firms' seasonal average protein content[39]—on average induces the firm to acquire 2.1 more suppliers, increasing its stock of integrated suppliers by nine percent on average. A same magnitude increase in relative demand for high quality fishmeal would lead the firm to source 29 percent more of its supply from integrated suppliers.

Our interpretation of the results in Table 4 is that firms vertically integrate *in order to be able to produce high quality output*. A potential alternative is that the liquidity that comes along with greater demand for quality (rather than the demand for quality itself) may affect firms' ability to integrate. That is, if firms' seasonal revenues are expected to be higher when demand for quality is high, they may be better able to access the capital necessary to vertically integrate, but actually integrate for other reasons than to satisfy the demand for high quality. While this is unlikely since not only acquisitions and sales of suppliers but also firms' actual input mix respond to quality demand shocks, we address the concern by including controls for total seasonal sales. This has little effect on the estimated coefficients.

In the first stage we use the 20 countries that import the most fishmeal from Peru (see Appendix Table A1). In Appendix Table A4 we show that our results are robust to instead using the 10 biggest importer countries and to using LASSO regressions to choose the importer countries whose demand fluctuations most affect quality grade exported.[40] The LASSO robustness check is in our view especially informative

[38]It is noteworthy that the IV coefficients in columns 3 and 4 are bigger than the OLS coefficients in columns 1 and 2. This probably reflects the relationship between output quality and vertical integration *at firm level* estimated in Section 4 partly reflecting a causal effect of organizational structure on output quality and partly other mechanisms, as discussed at the end of that section.

[39]The average seasonal protein content ranges between 63.5 and 67.8 percent protein in our sample, with a standard deviation of just over one.

[40]LASSO (least absolute shrinkage and selection operator) is a regression analysis method that performs both variable selection and

because the procedure picks the importer countries whose imports most affect the *specific* dimension of Peruvian fishmeal exports' characteristics we are interested in—their quality.

Since the existing literature that uses destination country demand shocks for identification often struggles with weak instruments, we compute the Kleibergen-Paap and Anderson-Rubin Wald test statistics. Comparing the statistics reported in Table 4 to the Stock-Yogo critical values[41], we reject the null hypothesis that our instruments are weak —the F statistic surpasses the 10 percent critical value—but fail the Kleibergen-Paap under-identification test when using the 20 countries that import the most fishmeal from Peru in the first stage (Table 4) Finally, we can reject the hypothesis that the coefficients on the excluded instruments are jointly zero when they are included in place of quality itself in the second stage regression using the Anderson-Rubin Wald test. It is important to note that weak instruments would bias the IV coefficients *downward*, i.e., towards the OLS coefficients, rather than upward. See Bastos *et al.* (2016) for a lengthier discussion of this issue in the context of "demand pull" instruments.

The strategic changes in organizational structure in response to changes in the composition of demand we have shown evidence of in this section are consistent with—and expected due to—the integration→quality relationship we established in Section 4. We conclude that Peruvian manufacturing firms are aware of, and act on, their greater ability to produce high quality grade output when integrated suppliers are used.

6 Organizational Structure and Supplier Behavior

6.1 Suppliers' trade-off between quantity- and quality-increasing actions

In Section 4, we saw that manufacturers produce higher quality output when they source a higher share of their inputs from integrated suppliers. In Section 5, we saw that manufacturers in fact vertically integrate in response to shocks to foreign demand for high quality products. In this section, we explore *how* the use of integrated suppliers benefits output quality. When the quality of inputs cannot be contracted upon, a firm's organizational structure may matter because the carrots and sticks that can be used to incentivize supplier actions to produce and deliver high quality inputs depend on the firm's structure.

What kind of supplier behavior is likely to improve the quality of inputs? The industry insiders we talked to all reported that an important determinant of fishmeal quality is the freshness of the fish at the time of processing, which depends on several factors. The first one is how the fish is stored while the boat is at sea. Some boats have an integrated cooling system on board, but the majority use ice to keep the catch fresh. Fish that has been stacked high vertically and heavily weighed down ("crushed") while stored on board will also be of lower quality when processed. The second factor that matters for freshness is how much time passes between when the fish is brought out of the water and when it is processed by a fishmeal plant. Boats' production technology thus implies a quantity-quality trade-off. Fishing close to port, bringing the catch to shore quickly, and not filling up the storage rooms with fish will increase the quality of the raw material delivered to plants, but these same behaviors in general entail a smaller catch per trip.

In the next sub-section we develop a theoretical framework that captures the implications of suppliers' trade-off between quantity- and quality-increasing actions for downstream firms. We then use the frame-

regularization in order to enhance the prediction accuracy and interpretability of the statistical model it produces, penalizing the model for including more regressors. LASSO selects Japan and Canada.

[41] Though Stock-Yogo's critical values are computed for the homoskedastic case, it is standard practice to compare the Kleibergen-Paap Wald test statistics to these critical values even when one reports standard errors that allow for heteroskedasticity.

work's predictions to guide our investigation of how integration can allow firms to incentivize desired supplier quality-increasing behavior.

6.2 Theoretical framework

In industries with vertically differentiated output quality, suppliers who are tasked with providing high quality inputs to high-end manufacturers have a natural alternative: they may simply sell their goods to lower-end manufacturers. Because the high-end manufacturers must consider the suppliers' incentive to maximize the inputs' value in the alternative (low-end) use, and because input quality is often thought to be partially observable but difficult to contract upon, the relationship between manufacturers and suppliers in such industries maps quite naturally into the classical Baker *et al.* (2002) model of organizational structure. We now sketch out a framework, slightly modifying Baker *et al.* (2002), to illustrate this intuition.

At a given point in time, there are two types of downstream firms. Quantity-oriented firms (P-firms) care only about (their share of) surplus that is due to the quantity of output that results from transactions with suppliers. We denote this surplus by P. Quality-oriented firms (Q-firms), however, care less about quantity, but also care about output quality. We denote the surplus associated with quality by Q. The total surplus generated from a transaction between a Q-firm and a supplier is $\alpha P + Q$, where $\alpha < 1$. There are several reasons why the market may be segmented in this way. Q-firms may for example be those with low marginal cost of producing quality, and/or those that have established relationships with buyers in importing countries that prefer high quality goods. We assume that suppliers who are serving Q-firms may also choose to supply P-firms, but that the reverse is not true.

A supplier chooses actions $a = \{a_1, a_2\}$ to produce inputs for downstream firms, where a_1 is the quantity-action and a_2 is the quality-action, and her cost of action is $c(a) = \frac{1}{2}(a_1^2 + a_2^2)$.

The quantity surplus P is high (P_H) with probability $p(a) = a_1$ and low (P_L) with probability $1 - p(a)$, and we let $P_H = P_L + \Delta P$. Similarly, we let $Q = Q_H$ with probability $q(a) = a_2$ and $Q = Q_L$ with probability $1 - q(a)$, where $Q_H = Q_L + \Delta Q$.[42] The overall surplus S is then:

$$S = \begin{cases} P - \frac{1}{2}(a_1^2 + a_2^2) & \text{for } P\text{-firms} \\ \alpha P + Q - \frac{1}{2}(a_1^2 + a_2^2) & \text{for } Q\text{-firms} \end{cases} \tag{4}$$

We assume that action a is unobservable to downstream firms, and that the realizations of Q and P are observable to both suppliers and downstream firms, but cannot be contracted upon. As in Baker *et al.* (2002), we consider four possible organizational structures:

1. Spot Outsourcing (Nonintegrated Asset Ownership, Spot Governance Environment)
2. Relational Outsourcing (Nonintegrated Asset Ownership, Relational Governance Environment)
3. Spot Employment (Integrated Asset Ownership, Spot Governance Environment)
4. Relational Employment (Integrated Asset Ownership, Relational Governance Environment)

The key distinction between outsourcing and employment is who owns the inputs produced. Under outsourcing, the supplier decides the use of the inputs. Under employment, the downstream firm determines the use of the inputs. In the spot market, suppliers get a share of the surplus generated. We assume

[42] We also assume $p(0) = q(0) = 0$ and $P_L < P_H < Q_L < Q_H$.

that downstream firms and suppliers have equal bargaining power in both sectors so that suppliers get half of the surplus generated. Under relational contracts, the contract terms are given by $(s, b_{LL}, b_{LH}, b_{HL}, b_{HH})$ where salary s is paid by downstream firms to their suppliers at the beginning of each period and b_{ij} is a bonus paid when $Q = Q_i$ ($i = H, L$) and $P = P_j$ ($j = H, L$).

Proposition 1. *There exists an area of the parameter space in which the first-best is achievable in both the P-sector and the Q-sector, with the first-best in the P-sector realized only under Relational Outsourcing and the first-best in the Q-sector realized only under Relational Employment.*

Proof. See Appendix. □

The intuition for why quality-oriented downstream firms may need to own upstream productive assets and hire the suppliers operating the assets as employees is as follows. Under any sort of outsourcing, suppliers are free to allocate the inputs produced to their alternative use. This means that the returns to the supplier on the spot market in both the quantity- and quality-oriented sectors depend on the value of the inputs produced in the quantity sector. As a result, when the value of the input is high in the quantity sector, quality-oriented firms may be unable to prevent the suppliers they interact with from breaking their relationship and selling the goods on the spot market. Hence, the realization of market conditions plays an important role in determining whether suppliers will honor a Relational Outsourcing contract. In contrast, under Relational Employment, the downstream firm has control over the inputs, and will choose to allocate them efficiently regardless of the value in the quantity sector. Hence, when ΔP is too high (relative to ΔQ), Relational Outsourcing is not a feasible strategy for Q-firms as their suppliers' non-reneging conditions would not be satisfied.

This framework predicts that industries with vertically differentiated output quality may be in a situation in which the degree of vertical integration is greater amongst quality-oriented firms, and that we should expect integrated suppliers to adopt a behavior more suited for production of high quality inputs than independent suppliers, who adopt a quantity-focused behavior.

6.3 Organizational structure and supplier average behavior

Guided by the version of the Baker *et al.* (2002) model with downstream quality differentiation presented above, we now explore how organizational structure matters for supplier behavior in the Peruvian fishmeal sector. We use the boat GPS data discussed in Section 3 to measure supplier behavior. We focus our analysis primarily on "switchers"; suppliers that are bought or sold by a fishmeal firm during our data period and observed delivering to a specific plant within the firm both before and after the change in status. We thus compare the behavior of a specific supplier delivering inputs to a specific downstream plant when the supplier is owned by the firm versus when it is not. In the majority of "switches", the supplier goes from being independently owned to being owned by the fishmeal firm supplied, but there are also cases in which the supplier is sold from a downstream firm to an independent owner (or from one fishmeal firm to another). As we saw in Section 5, one underlying driver of firms' acquisitions and sales of suppliers is the composition of demand: fishmeal manufacturers' integrate more of the boats that supply them when they face higher relative demand for high quality grade fishmeal and vice versa.

As shown in Appendix Table A6, the characteristics of integrated suppliers unsurprisingly differ from the characteristics of independent suppliers. On observable features such as the size of the boat, the power of its engine, and whether or not it has a cooling system installed, the average switcher falls in between the average always-independent boat and the average always-integrated boat, but closer to the latter. More importantly[43], we do not see any significant changes in suppliers' characteristics when switching in or out of integration with the plant supplied.

We proceed in three steps. In this sub-section, we show how a supplier's average behavior changes with being integrated with the plant supplied. In the next sub-section, we show how a supplier's behavioral response to a plant's need for input quality changes with integration. Finally, in Sub-section 6.5, we show how a supplier's behavioral response to an exogenous tightening of the trade-off between quantity- and quality-increasing actions changes with integration.

We begin by estimating:

$$\mathrm{B}_{ijt} = \alpha + \beta \mathrm{I}[\mathrm{VI} \times \text{supplies owner firm}]_{ijt} + \gamma_{ij} + \delta_t + \varepsilon_{ijt} \tag{5}$$

where B_{ijt} is a measure of the behavior of supplier i, delivering to plant j, on date t. $[\mathrm{VI} \times \text{supplies owner firm}]_{ijt}$ is an indicator for the supplier being integrated with the plant it delivers to on date t. We include date fixed effects (δ_t) to control for potential date specific behaviors and Supplier$\times$Plant fixed effects (γ_{ij}) so that we focus on how integration affects supplier behavior within a specific supplier-plant relationship. We cluster the standard errors at boat level throughout this section.

We report results for three different behaviors that are closely related to suppliers' quantity-quality trade-off: (i) Total quantity fished on the trip, (ii) Maximum distance from the port of delivery at which we observe the boat during the trip, and (iii) Total time at sea on the trip. When prioritizing quality, we expect boats to deliver lower quantities per trip and stay closer to port.

The results in Table 5 corroborate these predictions. The table demonstrates that suppliers take actions to deliver inputs of higher quality when integrated, at the cost of supplying a lower quantity per trip. Column 1 shows that, when integrated and supplying a parent plant, a boat delivers on average about ten percent lower quantity per trip compared to when it supplies the same plant while independent.[44] We interpret this result as indicative that boats dedicate more of their storage capacity to ice in order to keep the catch fresher and less crushed under other fish, when integrated. Column 2 shows that boats fish approximately five percent closer to the port of delivery when integrated. In Column 3, we see that boats spend on average three percent less time at sea on a trip when integrated.

Integration may enable knowledge transfer from manufacturers to their suppliers (see e.g. Atalay *et al.* , 2014). In Appendix Table A7 we show auxiliary results that are difficult to reconcile with such a story being the primary explanation behind the change in supplier behavior when integrated. We re-estimate the regression reported in Table 5 separately for two different types of switchers: those suppliers who go from being independently owned to being owned by the fishmeal firm supplied or vice versa[45], and those who go from being owned by another fishmeal firm to being owned by the fishmeal firm supplied or vice versa. The results are qualitatively similar in these two sub-samples, indicating that it is incentives that are due to the supplier's status *relative to the firm currently supplied* that matter for behavior.

[43]Differences in time-invariant supplier characteristics are controlled for in our analysis because we focus on *changes* in a supplier's behavior when it integrates with (or separates from) the plant supplied.

[44]We use the terms "independent" and "integrated" loosely in this section of the paper and do not always spell out that the terms refer to a supplier's status *relative to the specific firm that owns the plant supplied*.

[45]The reason we keep these two sub-groups as one sample rather than run the regression separately for each is that very few suppliers are sold from a fishmeal firm to an independent owner and observed supplying the initial owner both before and after the sale.

In Appendix Table A8, we show that relational outsourcing contracts, unlike employment contracts, appear not to be used to incentivize supplier quality-increasing actions in the Peruvian fishmeal industry, consistent with the framework in Sub-section 6.2. We show results for two different observable proxies for a supplier being engaged in a relational outsourcing contract with a downstream firm: (i) that the supplier delivers more than 80 percent of its fish to the same fishmeal firm (approximately the 75th percentile of the underlying distribution) for two consecutive production seasons, and (ii) that the supplier delivers to the same firm more than 10 times (approximately the 25th percentile of the underlying distribution) in a given production season and does so for three seasons in a row. The results show that a supplier supplying a given plant does not deliver fresher fish when engaged in repeated interactions with the firm in question, relative to more isolated instances of supplying the same plant. It is worth noting that we also do not observe the positive relationship between output quality and relational outsourcing that we see for use of vertically integrated suppliers, indicating that repeated interactions are not used to incentivize the delivery of high quality inputs in the Peruvian fishmeal sector.[46]

The results in columns 1-3 of Table 5 are consistent with the hypothesis that vertically integrating enables fishmeal firms to induce supplier behaviors that improve the quality of their inputs. A potential alternative interpretation is that suppliers simply put in less quantity-effort when integrated (and not paid proportional to quantity). Since such a story allows for plants' output quality benefitting from integrated suppliers putting in less quantity-effort, it is difficult to fully separate from the incentives-for-quality-actions hypothesis we focus on. An "accidental quality upgrading" story would raise questions about why fishmeal firms increasingly choose to acquire suppliers, however. The results in column 4 of Table 5 also do not support such a story. There we show that boats go out on more fishing trips when integrated.

6.4 Organizational structure and supplier behavioral response to plant input quality needs

In the previous sub-section, we analyzed how a supplier's *average* behavior changes with integration. In this sub-section, we explore how the way a supplier *changes* its behavior in response to a change in the supplied plant's need for input quality differs when integrated. A change in the need for input quality arises when the plant aims to produce fishmeal of the high quality type (for example because of a change in demand). As before, we compare periods when the supplier is integrated with the plant supplied and periods when the supplier is independent from but supplies the same plant. The marginal impact of the behavioral response of a single supplier on the output quality of the plant as a whole is likely to be limited. We thus interpret the coefficient of interest as the supplier's response to the plant's *intention* to produce higher quality output.

[46]These results are shown in Appendix Table A9, which is analogous to Table 3, for completeness. There we relate output quality not only to the share of inputs coming from integrated suppliers, but also to the share coming from suppliers under relational outsourcing contracts (as defined by the proxies described above). The estimated coefficients on the share of inputs coming from integrated suppliers remain positive and highly significant, while the estimated coefficients on the share coming from suppliers under relational outsourcing contracts are very small and insignificant. Results analogous to those shown for integrated suppliers in sub-sections 6.4 and 6.5 for suppliers under relational outsourcing contracts are available from the authors upon request; these show that such suppliers do not adjust their behavior to the input quality needs of the plant supplied and production conditions in the output quality-beneficial way that integrated suppliers do. Note that we "turn on" the inferred contract at the start of the relevant period, not when the "cut-off" used in the proxy is reached.

We estimate the following equation:

$$\begin{aligned} \mathrm{B}_{ijt} = \alpha &+ \beta_1 \text{ I[VI} \times \text{supplies owner firm]}_{ijt} \times \text{I[Low Quality]}_{jt} \\ &+ \beta_2 \text{ I[VI} \times \text{supplies owner firm]}_{ijt} \times \text{I[High Quality]}_{jt} \\ &+ \gamma_{ij} \times \text{I[High Quality]}_{jt} + \gamma_{ij} \times \text{I[Low Quality]}_{jt} + \delta_t + \varepsilon_{ijt} \end{aligned} \tag{6}$$

where $\text{I[Low Quality]}_{jt}$ is a dummy equal to 1 when plant j—i.e. the plant supplier i supplies at t—produces comparatively low quality fishmeal in the month date t falls within (and conversely for $\text{I[High Quality]}_{jt}$).[47] We include Supplier×Plant×Quality level fixed effects (that is, $\gamma_{ij} \times \text{I[High Quality]}_{jt}$ and $\gamma_{ij} \times \text{I[Low Quality]}_{jt}$) to focus on the supplier's *differential* response to the plant's input needs when integrated. The other variables are as defined in equation (5).

The results in Table 6 suggest that suppliers differentially adapt their quality behavior to the current needs of the downstream plant they supply when integrated. Column 1 shows that boats tend to deliver a lower quantity per trip when integrated with the plant supplied, regardless of whether the plant produces low or high quality at the time. However, columns 2 and 3 show that, when integrated, boats adjust their behavior so as to deliver fresher fish when the plant supplied is producing high quality output. When integrated, boats fish about seven percent closer to port and spend about six percent less time at sea, when the plant supplied is producing fishmeal of the high quality type.[48]

In Panel A of Appendix Table A10, we show that the estimated behavioral response to the input quality needs of the plant supplied is very similar if instead of focusing on switchers, we take a difference in differences approach. That is, we now compare suppliers that are either integrated or non-integrated with the plant supplied, when the plant is producing low quality versus high quality fishmeal. Relative to non-integrated suppliers, integrated suppliers prioritize delivering high quantities less but prioritize delivering inputs of high quality more when the plant supplied is producing high quality fishmeal, as seen in respectively column 1 and columns 2-3 of the panel. We view these results as corroborating those in Table 6, although we ultimately put more weight on results from within-supplier comparisons.

6.5 Organizational structure and supplier behavioral response to variation in production conditions

We have analyzed a supplier's change in (i) average behavior and (ii) behavioral response to a downstream need for input quality when the supplier vertically integrates with (or separates from) the plant it supplies. The findings are consistent with the hypothesis that downstream firms that aim to produce high quality output can more easily incentivize integrated suppliers to deliver inputs of the desired quality. In theory it is possible that the findings in sub-sections 6.3 and 6.4 are explained by downstream firms acquiring or selling suppliers exactly at times when those suppliers would have changed their behavior even if they had not been bought/sold by the firm that owns the plant supplied. To go further, we now explore how a supplier's response to an exogenous tightening of the trade-off between quantity- and quality-increasing actions depends on whether the supplier is owned by the firm it supplies or not.

[47] We define this dummy variable using our directly observed measure of quality at plant level. The dummy is equal to 1 if the share of the plant's production that is of high quality type is higher than the median in our sample.

[48] The last row of Table 6 shows that, with the exception of the first column, the behavior of integrated suppliers is significantly different when the downstream plant produces higher quality.

Plankton, the primary food source of Peruvian anchovies, can be used to predict the amount of fish present in a specific location (see also Axbard, 2016; Fluckiger & Ludwig, 2015). In the map in Panel (a) of Figure 2, we depict variation in plankton concentrations along the coast of Peru on a randomly picked date. Fish density in the ocean outside of fishmeal plants located in different parts of Peru differed considerably on the date shown. A dynamic version of the same map would show that the spatial distribution of plankton also varies extensively across time. Panel (b) of Figure 2 shows a map of plankton concentrations on the same date around the cluster of fishmeal plants in the town of Paracas. We see that boats concentrate their fishing in areas where plankton concentrations are highest.

To exploit the plankton variation shown in Figure 2, we take a split-sample approach. Specifically, we use 2015 data to identify the conditions that lead to availability of more and better fish, and thereafter exclude 2015 data from our regressions of interest. We first define good fishing conditions for a specific location. Geographically, the NASA plankton data is at the level of 0.1°-latitude×0.1°-longitude (roughly 10×10 kilometer) grid-cells×dates. We match the plankton data with information on how much fishing takes place in a given grid-cell, as inferred from GPS measures of boats' movements.

We first explore the likelihood that at least one boat fishes in a specific grid-cell on a specific date, as a function of the log plankton concentration.[49] The top panel of Figure 3 shows that the higher the log plankton concentration, the higher the likelihood that the location is chosen by at least one boat. The bottom panel shows the total quantity fished by all boats in the grid-cell as a function of log plankton concentration, controlling for boat fixed effects. The graph shows a positive and approximately linear relationship. Overall, Figure 3 makes clear that a higher plankton concentration is associated with better fishing conditions. We thus define a grid-cell×date as *good for fishing* if the log plankton concentration is greater than the median as defined over all grid-cells where at least one boat fishes at some point in 2015.

Our objective is to define how good the fishing conditions in the area outside of a cluster of fishmeal plants (i.e., a fishmeal port) are on a specific date. To do so, we must aggregate the grid-cells around each port to construct a port-specific measure. We first construct the share of fishing locations around a cluster of plants that are *good for fishing* on the date in question.[50] We then define a port×date as having *difficult conditions* if the share of grid-cells surrounding the location that are *good for fishing* is lower than the 10th percentile in the distribution of port×dates. In this sense, our definition of *difficult conditions* corresponds to dates when it is challenging to find fish nearby a cluster of plants. Figure 4 shows that on the dates when upstream production conditions are *difficult*, supply of fish to plants is on average 6 percent lower.

With this measure in hand, we explore whether the benefits of vertical integration to firms attempting to produce high quality output are greater when suppliers' opportunity cost of delivering high quality inputs is high. We estimate the following equation:

$$\begin{aligned}\text{Quality}_{jt} = \alpha + \beta_1 \text{VI}_{jt} + \beta_2 \text{Difficult conditions}_{jt} \\ + \beta_3 \text{VI}_{jt} \times \text{Difficult conditions}_{jt} + \beta_4 \text{HighTech}_{jt} + \gamma_j + \delta_t + \varepsilon_{jt} \qquad (7)\end{aligned}$$

where the firm×production season level continuous variable Difficult conditions$_{jt}$ is the average of port×date *difficult conditions* indicator variables for the locations where the firm's plants are located.

[49] We take logs because the distribution of plankton concentration is fat-tailed.

[50] We use only the locations that are within 145 kilometers of the port, the 95th percentile of the maximum distance from the port of delivery at which boats are observed during fishing trips. Note that we do not focus on the conditions facing a specific boat at a specific location because the boat's choice of where to fish is endogenous to its objectives on the date in question.

The results are presented in Table 7. The second row shows that if a downstream firm is subject to more *difficult conditions* upstream during a production season, the average quality grade of its fishmeal is significantly lower. We interpret this finding as evidence that when conditions are *difficult* according to our measure, it is more challenging for suppliers not only to deliver input quantity, but also quality.[51]

The third row of Table 7 shows that a firm can reduce the impact of *difficult conditions* on the quality of its output by integrating its suppliers. Since we normalize the *difficult conditions* variable to a mean of 0, the first row can be interpreted as the total correlation between the share of inputs coming from integrated suppliers and output quality. Comparing the first row of columns 1 and 2, and columns 3 and 4, we see that when we control for *difficult conditions* and its interaction with the VI share of inputs, the correlation between VI and output quality falls significantly.[52] This indicates that vertically integrating allows firms to partially overcome the challenges to producing high quality output that arise when upstream production conditions are difficult. This accounts for part of the correlation between integration and output quality we established in Section 4. In Panel A of Appendix Table A12 we show that these results are not sensitive to how we define difficult production conditions.[53]

We next explore whether the ability of integrated suppliers to help downstream firms mitigate difficult production conditions upstream is explained by their behavior at such times. Since the focus is now on suppliers, we can again use Supplier×Plant×date level data and estimate the folowing equation:

$$\begin{aligned} \mathrm{B}_{ijt} = \alpha &+ \beta_1 \mathrm{I}[\text{VI} \times \text{supplies owner firm}]_{ijt} \times \mathrm{I}[\text{Not difficult conditions}]_{ijt} \\ &+ \beta_2 \mathrm{I}[\text{VI} \times \text{supplies owner firm}]_{ijt} \times \mathrm{I}[\text{Difficult conditions}]_{ijt} \\ &+ \gamma_{ij} \times \mathrm{I}[\text{Difficult conditions}]_{ijt} + \gamma_{ij} \times \mathrm{I}[\text{Not Difficult conditions}]_{ijt} + \delta_t + \varepsilon_{ijt} \end{aligned} \tag{8}$$

where $\mathrm{I}[\text{Difficult conditions}]_{ijt}$ indicates that the fishing conditions around plant j's location are *difficult* on date t as defined above (and vice versa for $\mathrm{I}[\text{Not difficult conditions}]_{ijt}$). Similar to the approach in Subsection 6.4, we include Supplier×Plant×Difficult conditions fixed effects ($\gamma_{ij} \times \mathrm{I}[\text{Difficult conditions}]_{ijt}$ and $\gamma_{ij} \times \mathrm{I}[\text{Not Difficult conditions}]_{ijt}$) to focus on the supplier's differential response to production conditions when integrated. The other variables are as previously defined.

The results are in Table 8. Column 1 shows that a supplier tends to deliver a lower quantity of inputs on *difficult* production days when it is integrated with the plant supplied, relative to when it is not (though the estimate is not statistically significant). More importantly, boats fish 36 percent closer to port and spend 33 percent less time at sea on days when conditions are *difficult*, when integrated with the plant supplied relative to when not. Such changes in supplier behavior are likely to significantly affect the quality of the inputs available to the downstream firm. How suppliers adjust their behavior in response to an exogenous increase in the opportunity cost of quality-actions thus helps explain why it appears especially important for downstream output quality to use integrated suppliers when upstream production conditions are *difficult*. In Panel B of Appendix Table A12 we show that these results are not sensitive to our definition of difficult

[51]Greater plankton availability improves the fish's fatty acid profile, which in turn results in a fishmeal of higher protein content.

[52]In Appendix Table A11, we present similar regressions at the plant level (using the dichotomous measure of plant output quality available), and also when restricting the sample to the plants belonging to the fishmeal firm that shared its data with us. The results are qualitatively very similar to those in Table 7. One difference is that, to the extent that integrated suppliers' behavioral response to difficult production conditions helps plants produce fishmeal that is of prime rather than FAQ quality when upstream production conditions are difficult, this does not appear to explain the correlation between the use of integrated suppliers and the share of plants' production that is of prime quality.

[53]There we define a cluster of plants×date as having *difficult conditions* if the share of the grid-cells surrounding the location that are *good for fishing* is lower than the 20th percentile in the distribution of port×dates. The results are very similar to those in Table 7.

production conditions.[54]

In Panel B of Appendix Table A10, we show the estimated behavioral response to difficult production conditions is similar if instead of focusing on switchers we take a difference in differences approach. As in Panel A of the table (discussed above), we compare integrated (with the plant supplied) and non-integrated suppliers, now when production conditions are difficult versus when they are not. Relative to non-integrated suppliers, integrated suppliers take actions to deliver higher quality inputs when production conditions are difficult, as seen on columns 2-3 (although the estimated effects are attenuated relative to those in Table 8).[55] While we view the results in Panel B of Appendix Table A10 as corroborating those in Table 8, we ultimately put more weight on results from within-supplier comparisons.

In this sub-section we have shown that the boats that supply Peruvian fishmeal plants face a trade-off between taking quantity- and quality-increasing actions because of the technology they operate under. This trade-off is particularly pressing when production conditions are *difficult*. At such times, independent boats, whose pay depends directly on the quantity they deliver, engage in less quality-increasing behavior. In contrast, the *same* suppliers do not respond to difficult production conditions by prioritizing quality less when they are vertically integrated with the downstream firms they supply.

In sum, this section has shown that inputs *in a given supplier-plant relationship* on average come in smaller batches of higher quality fish when the supplier is owned by the plant, and that the difference is greater during periods (i) when the downstream firm is producing high quality output, and (ii) when plankton conditions increase the opportunity cost of quantity- and quality-increasing actions. The evidence thus supports the intuition laid out in the framework in Sub-section 6.2 for *how* vertical integration enables firms to produce higher quality output.

7 Conclusion

This paper identifies an overlooked motivation for and consequence of vertical integration in incomplete contracts settings: downstream firms strategically integrate to be able to produce output of high enough quality to sell to higher-paying consumers abroad. Integrating their suppliers allows manufacturing plants to incentivize desired behavior upstream and better control input quality.

Using within- and across-firm transaction level data and direct measures of the quality grades produced by downstream firms in the Peruvian fishmeal manufacturing industry, we first show that a vertically integrated organizational structure causally increases output quality. We then show that, when firms face higher relative demand from importers of high quality grades, they acquire more suppliers and replace input from independent suppliers with internally sourced input.

To understand the integration-quality relationship, we present a modified version of the classical Baker *et al.* (2002) model in which we allow for both quality- and quantity-oriented downstream firms, and two types of supplier actions; those that increase the quantity and those that increase the quality of inputs produced. The model predicts that, when suppliers are independently owned, their incentive to renege on

[54] There we define a port×date as having *difficult conditions* if the share of its fishing locations that are *good* is lower than the 15th percentile in the distribution. Note that the last row of Table 8 shows that the behavior of integrated boats is significantly different when conditions are *difficult*.

[55] As seen in Column 1, the quantity integrated suppliers deliver actually responds less to difficult production conditions than the quantity non-integrated suppliers deliver. Given that integrated suppliers deliver significantly lower quantities than integrated suppliers on "normal" (not *difficult*) production days, this is arguably unsurprising. More challenging conditions are likely to affect suppliers that generally take actions to deliver high quantities (i.e., non-integrated suppliers) more.

agreements with quality-oriented firms and shift to lower quality buyers may render the first-best actions unsustainable. Guided by the framework, we use "switchers" to explore how a supplier's behavior changes when integrated with the plant supplied. We find that fishing boats change their behavior consistently with the objective of delivering fresher fish—which allows their clients to produce high quality grade fishmeal—when integrated. They do so more when the downstream plant is in need of high quality input, and when the fishing conditions increase the supplier's opportunity cost of quality-increasing actions.

Overall this paper's results demonstrate a specific strategy that Peruvian manufacturing firms can and do adopt in order to upgrade the quality of their products, and why the vertical integration strategy works. In Figure 5, we plot a proxy for average quality that is available for most exporter countries—the average unit value of manufacturing products exported to the U.S.—against the share of those exports that is imported by "related party" downstream American companies. The figure shows clear evidence of an upward-sloping relationship between average unit values and related party import shares. The same relationship holds also within product categories.[56] This suggest that our findings reflect an association between vertical integration and manufacturing output quality that tends to hold on average across countries and manufacturing industries. Despite vertical integration *overall* being more common in developing countries (Acemoglu *et al.* , 2009; Macchiavello, 2011)—perhaps primarily for other reasons than firms' quality objectives—it may thus be that the extent of vertical integration observed among firms in the developing world is actually be suboptimally *low*, given that upgrading output quality is an essential element of export-driven economic development. Conversely, however, this paper's results also imply that improvements in contract enforcement can reduce the need for firms to make organizational choices that may be second-best but not first-best optimal.

[56] We show this in Appendix Table A13. In Figure 5, the variable plotted on the y-axis is $\hat{\gamma}_c$ from the regression $\text{log(unit value)}_{cpt} = \alpha_{pt} + \gamma_c + \varepsilon_{cpt}$, where $\text{log(unit value)}_{cpt}$ is the average log unit value of products exported from country c, of HS6 code p, in year t to the U.S.; α_{pt} is a product×year fixed effect; and γ_c is an origin country fixed effect. This regression is estimated using COMTRADE data from BACI. The variable plotted on the x-axis is $\hat{\delta}_c$ from the regression $\text{Related party share of U.S. imports}_{cpt} = \beta_{pt} + \delta_c + \upsilon_{cpt}$, where $\text{Related party share of U.S. imports}_{cpt}$ is the share of products exported from country c, of NAICS code p, in year t to the U.S. that are imported by related parties (usually other units of the same firm (Ruhl, 2015)); β_{pt} is a product×year fixed effect; and δ_c is an origin country fixed effect. This regression is estimated using data from the U.S. Census Bureau.

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TABLE 1: SUMMARY STATISTICS

		Mean	Sd
Firms	Total number of firms in sample	37	
	Export shipment (metric tons)	380	(351)
	Export Price ($/metric ton)	1454	(303)
	Number of destinations per season	7.05	(5.30)
	Number of export transactions per season	85	(99)
Plants	Total number of plants in sample	94	
	Has high technology	0.85	(0.36)
	High quality share of production	0.85	(0.35)
	Monthly production (metric tons)	3116	(3266)
	Processing capacity (metric tons/hour)	106	(54)
Boats	Number of boats operating per season	812	92
	Fraction owned by a downstream firm per season	0.28	(0.45)
	Fraction of boats made of steel per season	0.44	(0.50)
	Storage capacity (m3)	187	(165)
	Power engine (hp)	432	(343)
	Number of fishing trips per season	24.6	(13.3)
	Number of delivery ports per season	3.49	(1.90)
	Offload weight (metric tons) per trip	110	(110)
	Time at sea per trip (hours)	20.85	(9.96)
	Max. distance from the plant's port (kms)	76	(46)

Notes: This table gives summary statistics over our sample period. *Has high technology* is a dummy equal to 1 if the plant is equipped with steam drying technology. Plants' *processing capacity* measures the total weight of fish that can be processed in an hour. *Steel* is a binary variable equal to 1 if a boat is a steel boat (which tend to be bigger, better suited for industrial fishing, and are subject to different regulations). *Offload weight per trip* is the amount fished and delivered to a downstream firm on each trip. *Time at sea per trip* is the total time spent at sea on a fishing trip. *Max. distance from the plant's port* is the maximum distance between the boat and the port it delivers to on any trip.

TABLE 2: OUTPUT QUALITY AND VERTICALLY INTEGRATED SUPPLIERS

Panel A: Output quality and number of suppliers owned

Dep. var:	Protein content		Log(unit price)	
	(1)	(2)	(3)	(4)
Number of suppliers owned	0.021**	0.022**	0.002	0.002
	(0.009)	(0.010)	(0.002)	(0.002)
High technology share of capacity	No	Yes	No	Yes
Season FEs	Yes	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes	Yes
Mean of Dep. Var.	65.6	65.6	7.23	7.23
N	220	220	220	220

Panel B: Output quality and share of inputs from VI suppliers

Dep. var:	Protein content		Log(unit price)	
	(1)	(2)	(3)	(4)
Share of inputs from VI suppliers	1.080***	1.079***	0.090*	0.090*
	(0.266)	(0.267)	(0.047)	(0.047)
High technology share of capacity	No	Yes	No	Yes
Season FEs	Yes	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes	Yes
Mean of Dep. Var.	65.6	65.6	7.23	7.23
N	220	220	220	220

Panel C: Output quality and share of inputs from VI suppliers, controlling for suppliers and firm characteristics

Dep. var:	Protein content			Log(unit price)		
	(1)	(2)	(3)	(4)	(5)	(6)
Share of inputs from VI suppliers	1.056***	1.138***	1.106***	0.101**	0.098*	0.108**
	(0.335)	(0.279)	(0.345)	(0.048)	(0.048)	(0.049)
Share of inputs from steel boats	−0.065		−0.026	0.007		0.013
	(0.525)		(0.523)	(0.044)		(0.043)
Share of inputs from boats with high capacity	0.180		0.137	−0.115		−0.122
	(0.590)		(0.595)	(0.101)		(0.101)
Share of inputs from boats with cooling system	0.142		0.194	0.040		0.048
	(0.919)		(0.941)	(0.072)		(0.072)
Share of industry's production		1.711	1.747		0.249	0.258
		(2.217)	(2.207)		(0.167)	(0.194)
High technology share of capacity	Yes	Yes	Yes	Yes	Yes	Yes
Season FEs	Yes	Yes	Yes	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes	Yes	Yes	Yes
Mean of Dep. Var.	65.6	65.6	65.6	7.23	7.23	7.23
N	220	220	220	220	220	220

Notes: One observation is a firm during a production season. *Protein content* is the quantity weighted average of a measure of quality inferred from a database that provides weekly prices by quality. *Log(unit price)* is the log of the quantity weighted average unit price of exports during a season. *Share of inputs from VI suppliers* is the share of a firm's (or plant's) inputs that come from VI suppliers during a season. Steel boats tend to be bigger, better suited for industrial fishing, and are subject to different regulations. High capacity boats are boats whose hold capacity is in the upper quartile of the distribution. Boats without integrated cooling system use ice to keep fish fresh. *High technology share of capacity* controls for the share of the firm's total processing capacity (measured in metric tons per hour and averaged across all active plants within the firm) that uses steam drying technology. Standard errors clustered at the firm level are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

TABLE 3: OUTPUT QUALITY AND SHARE OF INPUTS FROM VERTICALLY INTEGRATED SUPPLIERS

	Panel A: All Plants			
Dep. var:	High Quality Share of Production			
	OLS	OLS	IV	IV
	(1)	(2)	(3)	(4)
Share of inputs from VI suppliers	0.102**	0.064**	0.115**	0.091**
	(0.038)	(0.030)	(0.051)	(0.045)
Mean of Dep. Var.	0.85	0.85	0.85	0.85
N	2647	2647	2487	2487
Has high technology	No	Yes	No	Yes
Month FEs	Yes	Yes	Yes	Yes
Plant FEs	Yes	Yes	Yes	Yes
	Panel B: Plants Within a Major Firm			
Dep. var:	Protein Content			
	OLS	OLS	IV	IV
	(1)	(2)	(3)	(4)
Share of inputs from VI suppliers	1.369**	1.338**	1.469*	1.390
	(0.654)	(0.656)	(0.807)	(0.918)
Mean of Dep. Var.	65.8	65.8	65.8	65.8
N	66	66	66	66
Has high technology	No	Yes	No	Yes
Month FEs	Yes	Yes	Yes	Yes
Plant FEs	Yes	Yes	Yes	Yes

Notes: Panel A includes data from all plants at the month or season level and uses the share of high quality production as a dependent variable—based on a dichotomous measure of quality that is available for all firms. Panel B focuses on a single firm for which more detailed plant level measures are available at the season level. *Log(unit price)* is the log of the quantity weighted average unit price of exports during a season. *Protein content* is the quantity weighted average of a measure of quality inferred with a database that provides weekly prices by quality. *Has high technology* controls for whether a plant is equipped or not with the steam drying technology. *Share of inputs from VI suppliers* is the share of a plant's inputs that come from VI suppliers in a given season. In IV specifications share of inputs from VI suppliers is instrumented by (a) the number of independent boats present in the plant's port in the season in question, excluding those that interact directly with the plant itself, and (b) the ratio of the number of boats in (a) to the total number of boats in the plant's port in that season that do not interact with the plant itself. Panel A includes standard errors clustered at the firm level in parentheses. Panel B includes robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 4: VERTICALLY INTEGRATED SHARE OF INPUTS AND OUTPUT QUALITY PRODUCED - INSTRUMENTING WITH FIRM-SPECIFIC DEMAND SHOCKS

	Panel A			
Dep. var:	Share of inputs from VI suppliers			
	OLS	OLS	IV	IV
	(1)	(2)	(3)	(4)
Protein content	0.030***	0.028***	0.128**	0.141***
	(0.010)	(0.009)	(0.051)	(0.054)
Log(Sales)		0.008		−0.042*
		(0.015)		(0.024)
Kleibergen-Paap LM p-value (Under-id)			0.40	0.38
Kleibergen-Paap Wald F statistic (Weak inst)			11.0	15.8
Anderson-Rubin Wald test p-value			0.000	0.000
Mean of Dep. Var.	0.45	0.45	0.45	0.45
N	220	220	220	220

	Panel B			
Dep. var:	Number of Boats			
	OLS	OLS	IV	IV
	(1)	(2)	(3)	(4)
Protein content	0.507	0.337	2.123**	2.366**
	(0.312)	(0.308)	(0.849)	(1.008)
Log(Sales)		0.822		−0.069
		(0.514)		(0.753)
Kleibergen-Paap LM p-value (Under-id)			0.40	0.38
Kleibergen-Paap Wald F statistic (Weak inst)			11.0	15.8
Anderson-Rubin Wald test p-value			0.000	0.000
Mean of Dep. Var.	24.5	24.5	24.5	24.5
N	220	220	220	220

Notes: One observation is a firm during a production season. *Share of inputs from VI suppliers* is the share of a firm's inputs that come from VI suppliers during a season. *Protein content* is the quantity weighted average of a measure of quality inferred with a database that provides weekly prices by quality. The instruments are interactions of indicators for positive exports in 2008 to each of the top 20 destination countries with leave-firm-out share of fishmeal exports from Peru towards the destination in the relevant year. In Appendix Table A4, we both include the top 10 destinations in the first stage and use a Lasso approach to chose destinations as robustness checks. Standard errors clustered at the firm level are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 5: SUPPLIER BEHAVIOR AND VERTICAL INTEGRATION

Dep. var:	Log(Quantity supplied)	Log(Max. distance from the plant's port)	Log(Total time spent at sea)	I[Boat goes on trip]
	(1)	(2)	(3)	(4)
I[VI × supplies owner firm]	-0.096^{***}	-0.054^{**}	-0.030	0.031^{**}
	(0.033)	(0.024)	(0.022)	(0.014)
Date FEs	Yes	Yes	Yes	Yes
Supplier × Plant FEs	Yes	Yes	Yes	No
Supplier FEs	No	No	No	Yes
N	315 442	137 251	159 724	3 235 182

Notes: One observation is a boat during a fishing trip. For Column (4), one observation is a boat on a given production day. *Quantity supplied* is the amount of fish the boat delivers to the plant per trip. *Max. distance from the plant's port* is maximum distance a specific boat is observed away from port. *Max. distance from the plant's port* can only be measured if the boat leaves from and arrives at the same port. *Total time at sea* is the amount of time the boat is away from port per trip. *I*[Boat goes on trip] is the likelihood that the boat goes out fishing on a specific **day**. The number of observations varies from one column to the next as GPS variables for a given trip are sometimes missing. Standard errors clustered at the boat owner level are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 6: OUTPUT QUALITY, SUPPLIER BEHAVIOR AND VERTICAL INTEGRATION

Dep. var:	Log(Quantity supplied)	Log(Max. distance from the plant's port)	Log(Total time spent at sea)
	(1)	(2)	(3)
I[VI × supplies owner firm] ×I[Plant producing low quality]	-0.133^{***}	0.017	-0.013
	(0.039)	(0.049)	(0.025)
I[VI × supplies owner firm] ×I[Plant producing high quality]	-0.066^{**}	-0.067^{***}	-0.042^{*}
	(0.033)	(0.025)	(0.12)
Date FEs	Yes	Yes	Yes
Supplier × Plant × High Quality FEs	Yes	Yes	Yes
N	314 383	136 538	158 918
p-val - Test: two coefficients equal	0.00	0.03	0.04

Notes: One observation is a supplier during a fishing trip. This table is similar to Table 5, but with I[VI × supplies owner firm] interacted with the quality produced by the downstream plant. *Quantity supplied* is the amount of fish the boat delivers to the plant per trip. *Max. distance from the plant's port* is maximum distance a specific boat is observed away from port. *Max. distance from the plant's port* can only be measured if the boat leaves from and arrives at the same port. *Total time at sea* is the amount of time the boat is away from port per trip. I[Plant producing high quality] is a dummy equal to one if the plant the supplier delivers to produces only high quality fishmeal. The number of observations varies from one column to the next as GPS variables for on given trip are sometimes missing. Standard errors clustered at the boat owner level are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 7: Output quality, vertically integrated share of inputs, and difficult upstream production conditions

Dep. var:	Protein content		Log(unit price)	
	(1)	(2)	(3)	(4)
Share of inputs from VI suppliers	1.313^{***}	1.132^{***}	0.137^{*}	0.115^{*}
	(0.407)	(0.380)	(0.071)	(0.063)
Difficult conditions		-1.566		-0.181^{***}
		(0.942)		(0.061)
Share VI $\times$ Difficult conditions		1.730^{**}		0.237^{***}
		(0.818)		(0.055)
High technology share of capacity	No	Yes	No	Yes
Season FEs	Yes	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes	Yes
Mean of Dep. Var.	65.4	65.4	65.4	7.20
N	179	179	179	179

Notes: One observation is a firm during a production season. The number of observations is lower than in Table 3 as observations after 2014 are excluded from the sample. (2015 is used to define the plankton concentration threshold at which the production conditions are considered difficult). *Log(unit price)* is the log of the quantity weighted average unit price of exports during a season. *Protein content* is the quantity weighted average of a measure of quality inferred from a database that provides weekly prices by quality. *Share of inputs from VI suppliers* is the share of a firm's inputs that come from VI suppliers during a season. *High technology share of capacity* controls for the share of the firm's total processing capacity (measured in metric tons per hour and averaged across all active plants within the firm) that uses steam drying technology. I[*Difficult conditions*] is a dummy equal to 1 when the share of "good fishing locations" $[$Log(plankton concentration)$>$0.5$]$ around a specific plant on a specific day is less than 5 percent (this corresponds to the bottom 10th percentile in the distribution of share of good fishing locations in our sample). This dummy is defined at the port-day level, while the regressions are at the firm-season level, so the dummy variable is averaged by firm-season to construct *Difficult conditions*. This variable can be interpreted as the share of days when the conditions are difficult for a specific firm during a production season. The variable is normalized to a mean equal to 0 in our sample so that the first row of this table can be interpreted as the correlation between the *Share of inputs from VI suppliers* and quality. Standard errors clustered at the firm level are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

TABLE 8: SUPPLIER BEHAVIOR, VERTICAL INTEGRATION AND DIFFICULT UPSTREAM PRODUCTION CONDITIONS

Dep. var:	Log(Quantity supplied)	Log(Max. distance from the plant's port)	Log(Total time spent at sea)
	(1)	(2)	(3)
I[VI $\times$ supplies owner firm] $\times$I[Not difficult conditions]	-0.092^{***} (0.032)	-0.039^{*} (0.023)	-0.017 (0.016)
I[VI $\times$ supplies owner firm] $\times$I[Difficult conditions]	-0.110 (0.139)	-0.355^{**} (0.138)	-0.330^{***} (0.037)
Date FEs	Yes	Yes	Yes
Supplier $\times$ Plant $\times$ Difficult conditions FEs	Yes	Yes	Yes
N	223 698	121 627	141 412
p-val - Test: 2 coefficients equal	0.90	0.02	0.00

Notes: One observation is a supplier during a fishing trip. The number of observations is lower than in Table 5 as the year 2015 is excluded from the sample. (This year is used to define the plankton concentration threshold at which the production conditions can be considered as difficult). *Quantity supplied* is the amount of fish the boat delivers to the plant per trip. *Max. distance from the plant's port* is maximum distance a specific boat is observed away from port. *Max. distance from the plant's port* can only be measured if the boat leaves from and arrives at the same port. *Total time at sea* is the amount of time the boat is away from port per trip. I[Boat goes on trip] is the likelihood that the boat goes out fishing on a specific **day**. The number of observations varies from one column to the next as GPS variables for a given trip are sometimes missing. I[*Difficult conditions*] is a dummy equal to 1 when the share of "good fishing locations" [Log(plankton concentration)>0.5] around a specific plant on a specific day is less than 5 percent (this corresponds to the bottom 10th percentile in the distribution of share of good fishing locations in our sample). The number of observations varies from one column to the next as GPS variables for on given trip are sometimes missing. Standard errors clustered at the boat owner level are included in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Figure 1: Paper Overview

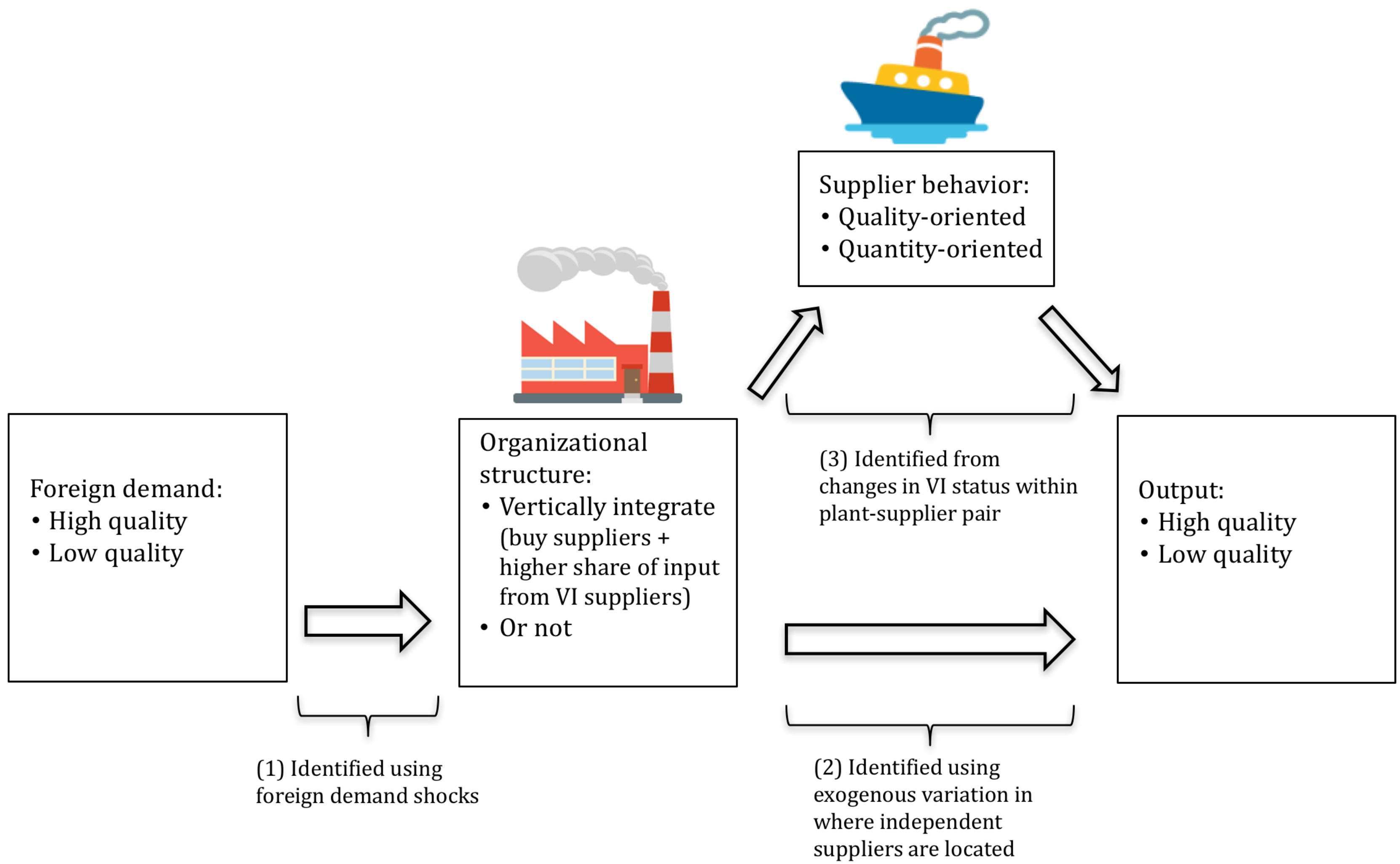
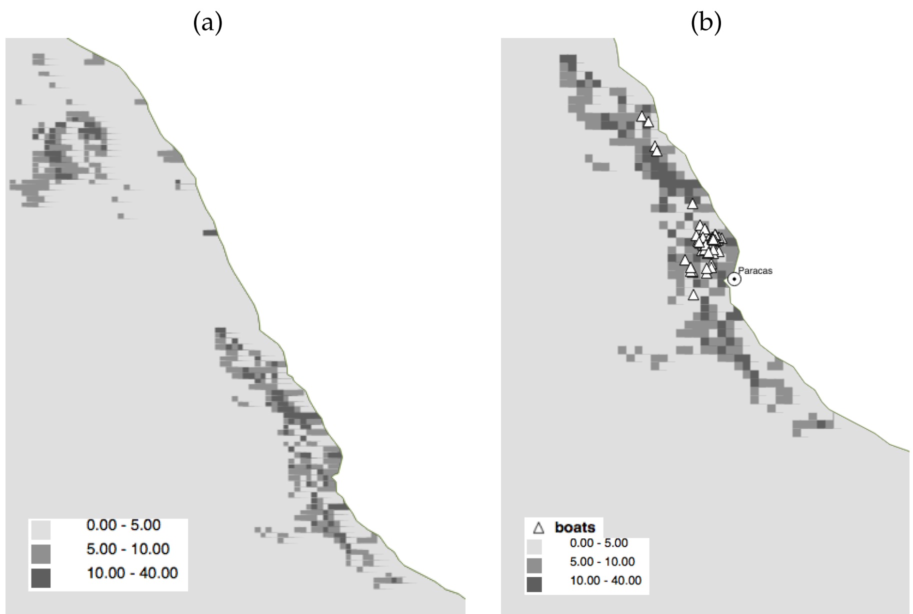


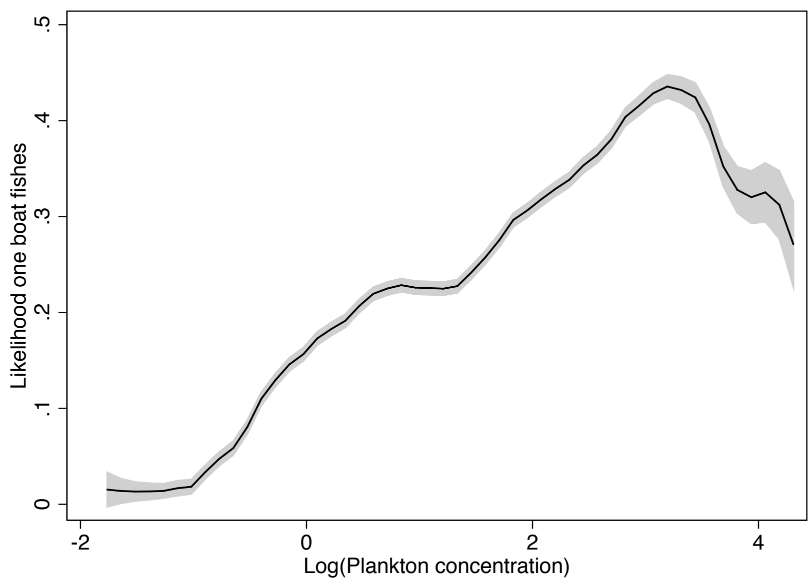
FIGURE 2: MAP OF PHYTOPLANKTON CONCENTRATION ALONG THE COAST OF PERU



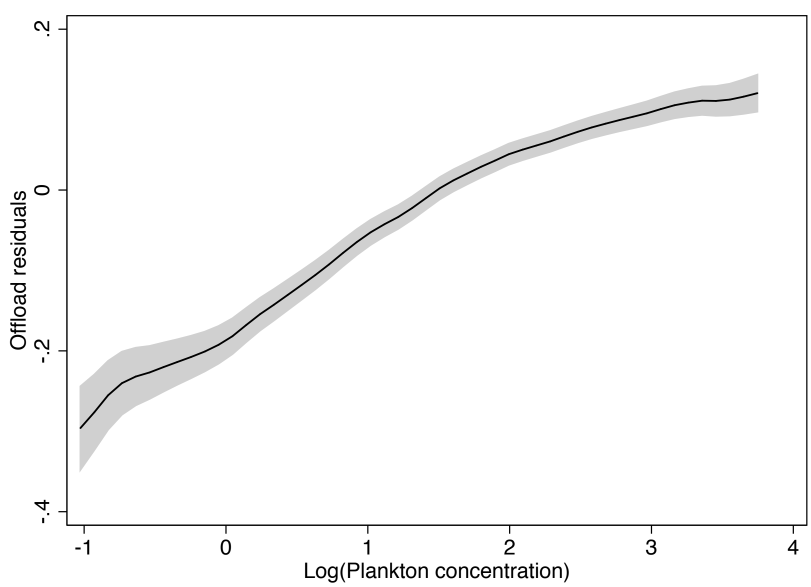
Notes: Panel (a) of this figure shows the distribution of plankton along the coast of Peru on December 10, 2012, as an example. A darker grey indicates a higher phytoplankton concentration (in mg/m^3). Panel (b) shows the same map zoomed around the port of Paracas, and the white triangles show where the boats offloading in Paracas last fished on a given trip. Fishing activity is proxied by the boat having a speed lower than than 2.9kms/hour maintained for at least half an hour as discussed in Section 3.

Figure 3: Plankton concentration, fishing locations, and quantity supplied

(a)

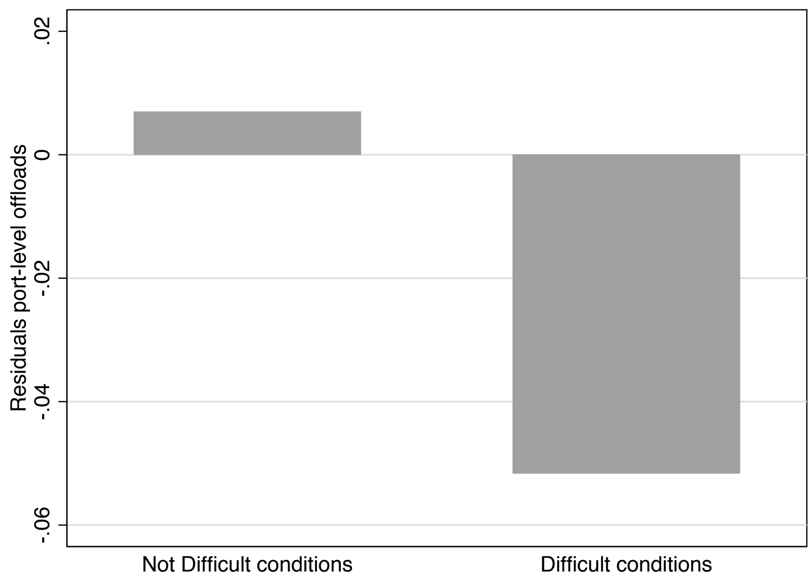


(b)



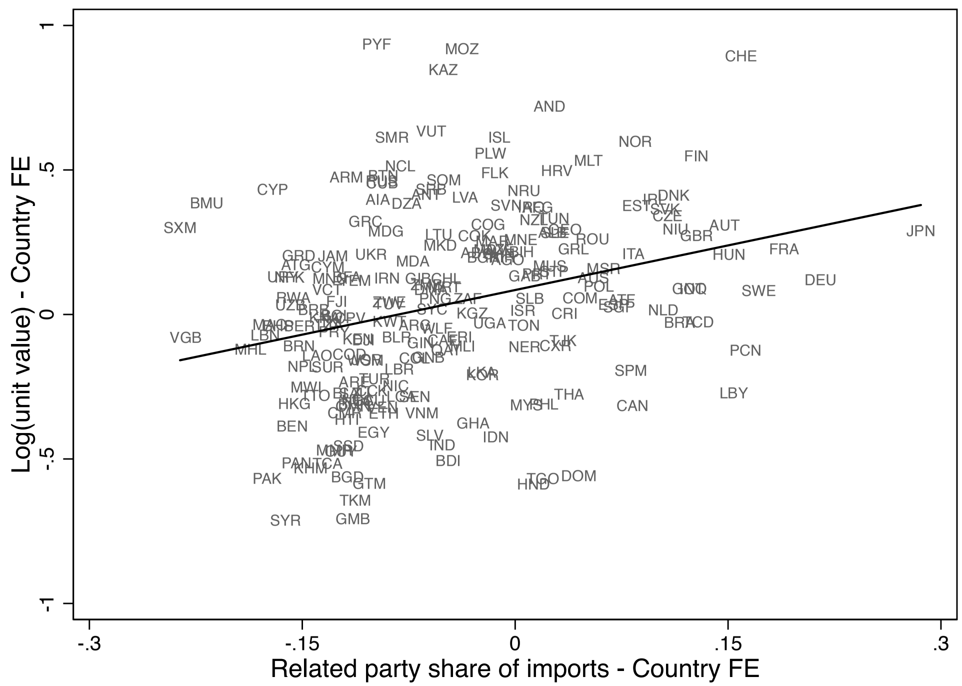
Notes: Panel (a) of this figure shows the likelihood that a boat fishes in a specific 0.1 degree$\times$0.1 degree (roughly 10 kilometer$\times$10 kilometer) grid-cell as a function of Log(phytoplankton concentration) at that location. Only locations were a boat fishes at least once during our data period and only the days when at least one boat goes out fishing are included. Panel (b) shows the residuals of a regression of quantity of fish caught in the grid-cell on boat fixed effects as a function of the Log(phytoplankton concentration). Catches are proxied by the boat having a speed lower than 2.9 kilometers/hour maintained for at least half an hour as discussed in Section 3.

Figure 4: Difficult upstream production conditions and quantity supplied



Notes: This graph shows how port residualized log fish offloads vary with fishing conditions. *Difficult conditions* is defined in Section 6.5

FIGURE 5: COUNTRIES' OUTPUT QUALITY AND VERTICAL INTEGRATION IN EXPORT MANUFACTURING



Notes: In this Figure, the variable plotted on the y-axis is $\hat{\gamma}_c$ from the regression log(unit value)$_{cpt} = \alpha_{pt} + \gamma_c + \varepsilon_{cpt}$, where log(unit value)$_{cpt}$ is the average log unit value of products exported from country c, of HS6 code p, in year t to the U.S.; α_{pt} is a product×year fixed effect; and γ_c is an origin country fixed effect. This regression is estimated using COMTRADE data from BACI (See **??**. The variable plotted on the x-axis is $\hat{\delta}_c$ from the regression Related party share of U.S. imports$_{cpt} = \beta_{pt} + \delta_c + \upsilon_{cpt}$, where Related party share of U.S. imports$_{cpt}$ is the share of products exported from country c, of NAICS code p, in year t to the U.S. that are imported by related parties (usually other units of the same firm (Ruhl, 2015)); β_{pt} is a product×year fixed effect; and δ_c is an origin country fixed effect. Related party share of U.S. imports$_{cpt}$ is constructed using data from the U.S. Census Bureau. The data is from 2005 to 2014.

Appendix

The P-sector

The first best in the P-sector maximizes

$$P - \frac{1}{2}(a_1^2 + a_2^2).$$

The first best actions are then $a_1 = \Delta P$ and $a_2 = 0$ and the first best surplus is $S = P_L + \frac{1}{2}(\Delta P)^2$. We now consider the actions taken under four possible organizational structures:

Spot Employment

Under spot employment, $a_1 = a_2 = 0$ and the surplus is $S = P_L$. The supplier provides no effort as the downstream party can simply take the output without paying the upstream party (see Baker *et al.* , 2002) .

Spot Outsourcing

Under spot outsourcing, firms and suppliers bargain over the surplus generated by the firm, with bargaining weights equal to $\frac{1}{2}$. More formally, the supplier chooses a_1, a_2 to maximize:

$$\frac{1}{2}P - \frac{1}{2}(a_1^2 + a_2^2).$$

The supplier chooses $a_1 = \frac{1}{2}\Delta P$ and $a_2 = 0$, hence the surplus is $S = P_L + \frac{3}{8}(\Delta P)^2$.

Relational Employment

Under both relational outsourcing and relational employment, we assume that firms provide bonuses to suppliers that depend on the realization of Q and P. Following Baker *et al.* (2002), we assume with some loss of generality that these bonuses take the form:

$$b_{ij} = b_i + \beta_j$$

where b_i is the surplus associated with the realization of Q, taking value b_L if $Q = Q_L$ and value $b_H = b_L + \Delta b$ if $Q = Q_H$. Similarly, β_j is the surplus associated with the realization of P, and can take values β_L if $P = P_L$ and $\beta_H = \beta_L + \Delta\beta$ if $P = P_L$. In the P sector, the supplier takes the first best level of effort if $\Delta\beta = \Delta P$, $\beta_L = P_L$ and $b_L = \Delta b = 0$.

Under relational employment, the firm owns the good. By reneging, the firm avoids making bonus payment b_j, but loses out on the dynamic value of the relationship, purchasing on the spot market in perpetuity. Letting π be the cost of the boat, a relational contract is sustainable under relational employment if the following no-reneging conditions hold:

- Firm: $-b_j + \frac{1}{r}D^{RE} \geq \frac{1}{r}D^{SO} + \pi$
- Supplier: $b_j + \frac{1}{r}U^{RE} \geq \frac{1}{r}U^{SO} - \pi$

Under the first best contract, these two conditions are equivalent to:

$$\max \beta_j - \min \beta_j = \Delta P \leq \frac{1}{r}[S^{FB} - S^{SO}] = \frac{1}{8r}(\Delta P)^2$$
$$\Rightarrow \Delta P \geq 8r$$

Relational Outsourcing

Under relational outsourcing, the supplier owns the good. By reneging, the firm avoids making bonus payment b_j, but also loses out on both the dynamic value of the relationship and the firm share of the current period surplus $\frac{1}{2}P_j$. By reneging, the supplier gains the spot market value of the good $\frac{1}{2}P_j$, but loses out on both the dynamic value of the relationship and the bonus payment this period. Given this, a relational contract is sustainable under relational outsourcing if the following no-reneging conditions hold:

- Firm: $-\beta_j + \frac{1}{r}D^{RO} \geq -\frac{1}{2}P_j + \frac{1}{r}D^{SO}$
- Supplier: $\beta_j + \frac{1}{r}U^{RO} \geq \frac{1}{2}P_j + \frac{1}{r}U^{SO}$

Under the first best contract, these two conditions are equivalent to:

$$\max\{b_j - \frac{1}{2}P_j\} - \min\{b_j - \frac{1}{2}P_j\} = \frac{1}{2}\Delta P \leq \frac{1}{r}[S^{RE} - S^{SO}] = \frac{1}{8r}(\Delta P)^2$$

$$\Rightarrow \Delta P \geq 4r.$$

The Q-sector

The first best in the Q-sector maximizes

$$\alpha P + Q - \frac{1}{2}(a_1^2 + a_2^2).$$

The first best actions are then $a_1 = \alpha \Delta P$ and $a_2 = \Delta Q$. The first best surplus is:

$$\alpha P_L + Q_L + \frac{1}{2}\alpha^2 \Delta P^2 + \frac{1}{2}\Delta Q^2$$

Spot Employment

Just as in the P sector, under spot employment $a_1 = a_2 = 0$. The surplus is $S = \alpha P_L + Q_L$.

Spot Outsourcing

A crucial difference between the Q and P sectors is the presence of an outside option for the supplier. In particular, the supplier may always go to the spot market in the P sector, and obtain $\frac{1}{2}P$. As a result, firms and suppliers bargain over the difference between the outside option to the supplier and the surplus to the firm. Hence, the supplier chooses a_1, a_2 to maximize:

$$\frac{1}{2}(\alpha P + Q - \frac{1}{2}P) + \frac{1}{2}P - \frac{1}{2}(a_1^2 + a_2^2).$$

The suppliers actions are given by: $a_1 = (\frac{1}{2}\alpha + \frac{1}{4})\Delta P$, and $a_2 = \frac{1}{2}\Delta Q$. The surplus is then:

$$\begin{aligned}
S =& \alpha P + Q - \frac{1}{2}\left(a_1^2 + a_2^2\right) \\
=& \alpha P_L + Q_L + \alpha \Delta P a_1 + \Delta Q a_2 - \frac{1}{2}\left(a_1^2 + a_2^2\right) \\
=& \alpha P_L + Q_L + (\frac{1}{2}\alpha^2 + \frac{1}{4}\alpha)\Delta P^2 + \frac{1}{2}\Delta Q^2 - \frac{1}{2}\left(\left[\frac{1}{4}\alpha^2 + \frac{1}{16} + \frac{1}{4}\alpha\right]\Delta P^2 + \frac{1}{4}\Delta Q^2\right) \\
=& \alpha P_L + Q_L + \left(\frac{3}{8}\alpha^2 + \frac{1}{8}\alpha - \frac{1}{32}\right)\Delta P^2 + \frac{3}{8}\Delta Q^2
\end{aligned}$$

Relational Employment

Under relational employment or relational outsourcing, the first best will be realized if $\Delta b = \Delta Q$ and $\Delta \beta = \alpha \Delta P$. Similarly to the P sector, the no-reneging conditions under **relational employment** are given by (assuming spot outsourcing is more efficient than spot employment):

- Downstream: $-b_{ij} + \frac{1}{r}D^{RE} \geq \frac{1}{r}D^{SO} + \pi$
- Upstream: $b_{ij} + \frac{1}{r}U^{RE} \geq \frac{1}{r}U^{SO} + \pi$

Under the first best contract, these two conditions are equivalent to:

$$\max b_{ij} - \min b_{ij} = \Delta b + \Delta \beta = \alpha \Delta P + \Delta Q$$

$$\leq \frac{1}{r}[S^{RE} - S^{SO}]$$

$$= \frac{1}{r}\left(\left[\frac{1}{8}\alpha^2 - \frac{1}{8}\alpha + \frac{1}{32}\right]\Delta P^2 + \frac{1}{8}\Delta Q^2\right).$$ [57]

Relational Outsourcing

The no-reneging conditions under relational outsourcing (again assuming spot employment is more efficient than spot outsourcing) are given by:

- Downstream: $b_{ij} - \frac{1}{2}[(\alpha + \frac{1}{2})P_j + Q_i] \leq \frac{1}{r}(D^{RO} - D^{SO})$
- Upstream: $b_{ij} - \frac{1}{2}[(\alpha + \frac{1}{2})P_j + Q_i] \geq \frac{1}{r}(U^{RO} - U^{SO})$

[57] In general, this condition may be written as $\alpha \Delta P + \Delta Q \leq \frac{1}{r}[S^{RE} - \max\{S^{SE}, S^{SO}\}]$

Under the first best contract, these two conditions are equivalent to :

$$\begin{aligned}
&\max\{b_{ij} - \frac{1}{2}[(\alpha+\frac{1}{2})P_j + Q_i]\} - \min\{b_{ij} - \frac{1}{2}[(\alpha+\frac{1}{2})P_j + Q_i]\} \\
&= |\Delta b - \frac{1}{2}\Delta Q| + |\Delta\beta - \frac{1}{2}(\alpha+\frac{1}{2})\Delta P| \\
&\leq \frac{1}{r}[S^{RE} - S^{SO}] = \frac{1}{r}[S^{FB} - S^{SO}] \\
&= \frac{1}{r}\left(\left[\frac{1}{8}\alpha^2 - \frac{1}{8}\alpha + \frac{1}{32}\right]\Delta P^2 + \frac{1}{8}\Delta Q^2\right)
\end{aligned}$$

Note that when $\alpha < \frac{1}{2}$ the lefthand side of the inequality may be written as:

$$|\Delta b - \frac{1}{2}\Delta Q| + |\Delta\beta - \frac{1}{2}(\alpha+\frac{1}{2})\Delta P| = \frac{1}{2}\Delta Q + \left(\frac{1}{4} - \frac{1}{2}\alpha\right)\Delta P.$$

Proof of Proposition 1

To prove the proposition, we simply need to show that there exist some parameter values for which the first best may be achieved under relational outsourcing but not relational employment in the P sector, and under relational employment but not relational outsourcing in the Q sector. First, consider a set of parameter values in which $\alpha < \frac{1}{2}$ and the surplus is greater in the Q sector under spot outsourcing as compared to spot employment.

In the P sector, first best may be achieved in under relational outsourcing but not relational employment if

$$\frac{\Delta P}{4} \geq r > \frac{\Delta P}{8}.$$

In the Q sector, first best may be achieved in under relational employment but not relational outsourcing if the following set of inequalities hold:

$$\frac{1}{2}\Delta Q + \left(\frac{1}{4} - \frac{1}{2}\alpha\right)\Delta P > \frac{1}{r}\left(\left[\frac{1}{8}\alpha^2 - \frac{1}{8}\alpha + \frac{1}{32}\right]\Delta P^2 + \frac{1}{8}\Delta Q^2\right) > \alpha\Delta P + \Delta Q.$$

To satisfy the condition in the P-Sector, consider the case where $r = \frac{2\Delta P}{15}$. To further simplify, let $\Delta Q = \gamma\Delta P$. We can then rewrite the above set of inequalities as:

$$\left(\frac{1}{2}\gamma + \frac{1}{4} - \frac{1}{2}\alpha\right)\Delta P > \frac{15}{2}\left[\frac{1}{8}\alpha^2 - \frac{1}{8}\alpha + \frac{1}{32} + \frac{\gamma^2}{8}\right]\Delta P > (\alpha+\gamma)\Delta P.$$

This set of inequalities holds, for example, when $\alpha = 0$ and $\gamma = \frac{1}{3}$, which reduces the above to:

$$\frac{10}{24}\Delta P > \left[\frac{195}{576}\right]\Delta P > \frac{1}{3}\Delta P.$$

Given that all aspects of the inequality are continuous, note that this also must hold for some $\alpha > 0$. Finally, note that the assumptions that $\alpha < \frac{1}{2}$ and that the surplus is higher under relational outsourcing as compared to relational employment are sustained when $\alpha = 0$, $\gamma = \frac{1}{3}$ and $r = \frac{2\Delta P}{15}$.

Appendix tables

TABLE A1: MAIN IMPORTERS OF PERUVIAN FISHMEAL AND AVERAGE QUALITY IMPORTED

	Total Weight (1000 metric tons)	Average Protein content	Sd(Protein content)
CHINA	4266	66.06	1.60
GERMANY	972	65.42	1.62
JAPAN	545	66.12	1.69
CHILE	305	66.60	1.51
VIETNAM	277	65.91	1.59
TAIWAN	248	66.02	1.71
UNITED KINGDOM	147	65.26	1.62
TURKEY	128	64.91	1.52
INDONESIA	94	66.16	1.64
SPAIN	90	65.44	1.61
AUSTRALIA	85	66.06	1.80
CANADA	66	65.76	1.52
FRANCE	55	65.59	1.72
GREECE	42	66.02	1.49
SOUTH KOREA	24	66.56	1.46
ITALY	21	64.97	1.52
ECUADOR	20	65.49	0.89
BULGARIA	15	65.42	1.75
VENEZUELA	13	66.67	1.64
PHILIPPINES	12	64.92	1.47

Notes: This table reports the top 20 importers of Peruvian fishmeal, the total quantity imported over the whole period of our sample, the average quality imported and the standard deviation of the quality imported across all transactions.

Table A2: Decomposition of the growth rate of Share of inputs from VI suppliers

$$\text{Growth (Share VI)}_{i,t} \approx \log\left(\frac{\text{Share VI}_{i,t+1}}{\text{Share VI}_{i,t}}\right) = \log\left(\frac{\frac{\text{VI}_{i,t+1}}{\text{Total}_{i,t+1}}}{\frac{\text{VI}_{i,t}}{\text{Total}_{i,t}}}\right) = \underbrace{\log\left(\frac{\frac{\text{VI}_{i,t+1}}{\text{Total}_{t+1}}}{\frac{\text{VI}_{i,t}}{\text{Total}_{t}}}\right)}_{A} - \underbrace{\log\left(\frac{\frac{\text{Total}_{i,t+1}}{\text{Total}_{t+1}}}{\frac{\text{Total}_{i,t}}{\text{Total}_{t}}}\right)}_{B}$$

	Total	A	B
Growth	2.9%	2.2%	0.7%
Relative Contribution		77%	23%

Notes: The growth rate of "Share $\text{VI}_{i,t}$" – the share of the inputs sourced by firm i during production season t that comes from vertically integrated suppliers – can be decomposed as presented in the first row of this table. $\text{VI}_{i,t}$ and $\text{Total}_{i,t}$ is respectively the *amount* of inputs firm i sources from vertically integrated suppliers and in total during season t, and Total_t is the total amount of inputs sourced by the industry as a whole during season t. Term A can then be interpreted as the contribution to the growth rate of Share $\text{VI}_{i,t}$ that comes from increasing solely the (relative) amount of inputs coming from integrated suppliers. Term B can be interpreted as the contribution of a firm decreasing the (relative) amount of inputs sourced from all suppliers. The table gives the growth rate of "Share $\text{VI}_{i,t}$", Term A and Term B.

TABLE A3: OUTPUT QUALITY AND SHARE OF INPUTS FROM VERTICALLY INTEGRATED SUPPLIERS - FIRST STAGE

Dep. var:	Share of inputs from VI suppliers			
	All Plants		Plants Within a Major Firm	
	(1)	(2)	(3)	(4)
Number of Independent Boats in Port	-0.001^{***}	-0.001^{***}	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Share of Independent Boats in Port	-0.313^{***}	-0.314^{***}	-0.412^{**}	-0.398^{*}
	(0.027)	(0.027)	(0.200)	(0.207)
Kleibergen-Paap LM p-value (Under-id)	0.038	0.038	0.005	0.006
Kleibergen-Paap Wald F statistic (Weak inst)	70.66	68.54	3.61	3.06
Anderson-Rubin Wald test p-value	0.04	0.02	0.24	0.31
Has High Technology	No	Yes	No	Yes
Month FEs	Yes	Yes	Yes	Yes
Plant FEs	Yes	Yes	Yes	Yes

Notes: Results from the first stage of IV specifications reported in Table 3. Share of inputs from VI suppliers is instrumented by (a) the number of independent boats present in the plant's port in the season in question, excluding those that interact directly with the plant itself, and (b) the ratio of the number of boats in (a) to the total number of boats in the plant's port in that season that do not interact with the plant itself. The left two columns include standard errors clustered at the firm level in parentheses. the right two columns include robust standard errors in parentheses.

TABLE A4: VERTICALLY INTEGRATED SHARE OF INPUTS AND OUTPUT QUALITY PRODUCED – INSTRUMENTING WITH FIRM-SPECIFIC DEMAND SHOCKS - ROBUSTNESS CHECKS

	Panel A			
Dep. var:	Share of inputs from VI suppliers			
	Top 10 Destinations		Lasso	
Protein content	0.123^{**}	0.138^{**}	0.142^{**}	0.150^{**}
	(0.054)	(0.054)	(0.057)	(0.061)
Log(Sales)		-0.040		-0.046^{*}
		(0.029)		(0.028)
Kleibergen-Paap LM p-value (Under-id)	0.31	0.40	0.11	0.16
Kleibergen-Paap Wald F statistic (Weak inst)	2.30	3.36	6.89	4.93
Anderson-Rubin Wald test p-value	0.072	0.079	0.406	0.398
Mean of Dep. Var.	0.45	0.45	0.45	0.45
N	220	220	220	220
Season FEs	Yes	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes	Yes

Notes: One observation is a firm during a production season. *Share of inputs from VI suppliers* is the share of a firm's inputs that come from VI suppliers during a season. *Protein content* is the quantity weighted average of a measure of quality infered with a database that provides weekly prices by quality. The instruments are interactions of indicators for positive exports in 2008 to destination countries with leave-firm-out share of fishmeal exports from Peru towards the destination in the relevant year. We both include the top 10 destinations in the first stage and use a Lasso approach to chose destinations as robustness checks. Standard errors clustered at the firm level are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE A5: VERTICALLY INTEGRATED SHARE OF INPUTS AND OUTPUT QUALITY PRODUCED – INSTRUMENTING WITH FIRM-SPECIFIC DEMAND SHOCKS - FIRST STAGE

Dep. var:	Protein content					
	Top 20 Destinations		Top 10 Destinations		Lasso	
	(1)	(2)	(3)	(4)	(5)	(6)
Indonesia	69.972***	64.735**	56.751**	54.022**	61.494***	57.915***
	(26.838)	(27.919)	(26.951)	(25.406)	(19.927)	(18.922)
South Korea	−98.818	−100.589			−99.535*	−103.097*
	(61.087)	(71.081)			(51.153)	(60.673)
China	−2.241	−2.203	−2.098	−2.017		
	(2.141)	(1.999)	(2.100)	(1.967)		
Germany	0.167	0.027	0.068	0.004		
	(1.726)	(1.793)	(1.711)	(1.813)		
Japan	−6.886	−7.401	−6.142	−6.950	−5.795	−6.110
	(7.510)	(6.996)	(8.252)	(7.783)	(6.748)	(6.377)
Chile	−4.762*	−3.738	−5.969***	−5.044**	−4.371***	−3.765*
	(2.603)	(2.481)	(2.115)	(2.062)	(2.130)	(2.216)
Vietnam	6.981	4.586	1.046	−0.832		
	(7.471)	(7.565)	(7.566)	(6.759)		
Taiwan	−12.450	−9.914	−7.373	−4.915		
	(20.169)	(19.243)	(19.807)	(18.423)		
United Kingdom	−19.492*	−14.959	−10.452	−9.866	−19.308***	−14.936*
	(10.088)	(9.879)	(9.887)	(7.901)	(7.848)	(7.839)
Turkey	−4.998	−3.598	−6.995	−6.016		
	(8.260)	(9.060)	(6.210)	(6.935)		
Spain	−7.679	−3.022	16.311	14.664		
	(12.283)	(13.107)	(15.452)	(14.445)		
Australia	0.742	1.246				
	(17.303)	(13.261)				
Canada	−1.905	−8.737				
	(23.176)	(24.443)				
France	85.177*	54.714			78.745**	54.342
	(48.641)	(56.565)			(36.967)	(42.153)
Italy	24.686	26.760				
	(51.156)	(52.203)				
Bulgaria	−6.965	−4.527				
	(47.673)	(50.403)				
Venezuela	20.975	−4.654				
	(102.539)	(105.883)				
Belgium	76.085	53.787				
	(122.671)	(127.219)				
Philippines	53.752	48.170			37.282	35.118
	(116.560)	(103.206)			(108.501)	(94.188)
India	−115.176	−109.410			−100.153**	−101.626**
	(75.185)	(69.163)			(46.060)	(46.974)
Log(Sales)	No	Yes	No	Yes	No	Yes
Season FEs	Yes	Yes	Yes	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes	Yes	Yes	Yes

Notes: First stage results for IV specifications reported in Tables 4 and A4. One observation is a firm during a production season. *Share of inputs from VI suppliers* is the share of a firm's inputs that come from VI suppliers during a season. *Protein content* is the quantity weighted average of a measure of quality inferred with a database that provides weekly prices by quality. The instruments in Table 4 are interactions of indicators for positive exports in 2008 to each of the top 20 destination countries with leave-firm-out share of fishmeal exports from Peru towards the destination in the relevant year. In Appendix Table A4, we both include the top 10 destinations in the first stage and use a Lasso approach to chose destinations as robustness checks. Standard errors clustered at the firm level are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE A6: SUPPLIER CHARACTERISTICS

	Offload weight per trip (metric tons)	Cooling system	Capacity (m3)	Power engine (hp)	Max. Distance from the plant's port (kms)
Wooden	41.00	0.00	65.73	215.40	56.10
	(16.24)	(0.06)	(27.34)	(94.78)	(7.74)
Steel - Independent	104.03	0.09	219.30	412.31	81.15
	(40.77)	(0.28)	(84.35)	(189.82)	(13.43)
Steel - Switchers	148.88	0.25	301.18	616.30	92.25
	(0.43)	(0.444)	(129.92)	(328.51)	(15.37)
Steel - VI	181.62	0.34	382.00	769.96	97.29
	(68.13)	(0.47)	(137.11)	(352.52)	(12.62)

Notes: *Offload weight* is the amount fished on a trip. *Maximum distance from port* is the maximum distance at which a boat is from the port on a fishing trip. Steel boats are generally bigger, better suited for industrial fishing, and are subject to different regulations. Wooden boats cannot be owned by fishmeal firms. *Independent* boats are owned by an individual or a company that is not a fishmeal company. *Switchers* are boats that move from VI to Independent or from Independent to VI at some point in our data. *VI* are boats that remain vertically integrated during the whole sample of our data.

TABLE A7: SUPPLIER BEHAVIOR AND VERTICAL INTEGRATION

Panel A: Switchers only (Independent to VI or VI to Independent)			
Dep. var:	Log(Quantity supplied)	Log(Max. distance from the plant's port)	Log(Total time spent at sea)
	(1)	(2)	(3)
I[VI × supplies owner firm]	-0.057^{*}	-0.034	-0.002
	(0.032)	(0.025)	(0.022)
Date FEs	Yes	Yes	Yes
Supplier × Plant FEs	Yes	Yes	Yes
N	315 442	137 278	159 724

Panel B: Changing ownership (VI to VI)			
Dep. var:	Log(Quantity supplied)	Log(Max. distance from the plant's port)	Log(Total time spent at sea)
	(1)	(2)	(3)
I[VI × supplies owner firm]	-0.147^{***}	-0.082^{**}	-0.073^{**}
	(0.031)	(0.033)	(0.030)
Date FEs	Yes	Yes	Yes
Supplier × Plant FEs	Yes	Yes	Yes
N	315 442	137 274	159 724

Notes: One observation is a supplier during a fishing trip. This Table is similar to Table 5 but in Panel A, identification only comes from switchers - suppliers that were independent and are acquired at some point by a fishmeal company or by suppliers that were integrated and are sold by a fishmeal company and become independent. In Panel B, identification only comes from integrated suppliers that are sold by a fishmeal company and bought by another fishmeal company. *Quantity supplied* is the amount of fish the boat delivers to the plant per trip. *Max. distance from the plant's port* is maximum distance a specific boat is observed away from port. *Max. distance from the plant's port* can only be measured if the boat leaves from and arrives at the same port. *Total time at sea* is the amount of time the boat is away from port per trip. I[Boat goes on trip] is the likelihood that the boat goes out fishing on a specific **day**. The number of observations varies from one column to the next as GPS variables for a given trip are sometimes missing. Standard errors clustered at the boat owner level are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE A8: SUPPLIER BEHAVIOR AND RELATIONAL OUTSOURCING

Panel A: Relational outsourcing = 80% of offloads to the same firm for 2 consecutive production seasons			
Dep. var:	Log(Quantity supplied)	Log(Max. distance from the plant's port)	Log(Total time spent at sea)
	(1)	(2)	(3)
I[Relational × supplies relational firm]	0.010	0.016	−0.000
	(0.008)	(0.010)	(0.007)
Date FEs	Yes	Yes	Yes
Supplier × Plant FEs	Yes	Yes	Yes
N	315 442	137 278	159 724

Panel B: Relational Outsourcing = more than 10 interactions with the same firm for at least 3 consecutive production seasons			
Dep. var:	Log(Quantity supplied)	Log(Max. distance from the plant's port)	Log(Total time spent at sea)
	(1)	(2)	(3)
I[Relational × supplies relational firm]	−0.009	0.026	0.002
	(0.018)	(0.026)	(0.019)
Date FEs	Yes	Yes	Yes
Supplier × Plant FEs	Yes	Yes	Yes
N	315 442	137 278	159 724

Notes: One observation is a boat during a fishing trip. For Column (4), one observation is a boat on a given production day. *Quantity supplied* is the amount of fish the boat delivers to the plant per trip. *Max. distance from the plant's port* is maximum distance a specific boat is observed away from port. *Max. distance from the plant's port* can only be measured if the boat leaves from and arrives at the same port. *Total time at sea* is the amount of time the boat is away from port per trip. I[Boat goes on trip] is the likelihood that the boat goes out fishing on a specific **day**. The number of observations varies from one column to the next as GPS variables for a given trip are sometimes missing. In Panel A, we define an independent boat as being under a relational contract if the boat delivers more than 80% of its offloads (75th percentile) to the same fishmeal firm for 2 consecutive fishing seasons. In Panel B, we define an independent boat as being under a relational contract if the boat interacts more than 10 times (25th percentile) with the same firm during a fishing season and so, for at least 3 consecutive fishing seasons. Standard errors clustered at the boat owner level are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE A9: OUTPUT QUALITY AND SHARE OF INPUTS FROM VERTICALLY INTEGRATED SUPPLIERS AND SUPPLIERS UNDER A RELATIONAL OUTSOURCING CONTRACT

Panel A: First definition of relational outsourcing				
Dep. var:	Protein content		Log(unit price)	
	(1)	(2)	(3)	(4)
Share of inputs from VI suppliers	1.044***	1.081***	0.088	0.090*
	(0.342)	(0.340)	(0.053)	(0.052)
Share of inputs from relational suppliers	−0.157	0.006	−0.008	0.003
	(0.505)	(0.441)	(0.037)	(0.039)
High technology share of capacity	No	Yes	No	Yes
Season FEs	Yes	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes	Yes
Mean of Dep. Var.	65.6	65.6	7.23	7.23
N	220	220	220	220
Panel B: Second definition of relational outsourcing				
Dep. var:	Protein content		Log(unit price)	
	(1)	(2)	(3)	(4)
Share of inputs from VI suppliers	1.072***	1.063***	0.089*	0.088*
	(0.268)	(0.269)	(0.047)	(0.047)
Share of inputs from relational suppliers	0.208	0.409	0.018	0.032
	(1.975)	(1.814)	(0.167)	(0.152)
High technology share of capacity	No	Yes	No	Yes
Season FEs	Yes	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes	Yes
Mean of Dep. Var.	65.6	65.6	7.23	7.23
N	220	220	220	220

Notes: One observation is a firm during a production season. The regressions are similar to the ones in Table 3 but control for the share of inputs from independent suppliers under a relational contract with the downstream firm. *Protein content* is the quantity weighted average of a measure of quality inferred from a database that provides weekly prices by quality. *Log(unit price)* is the log of the quantity weighted average unit price of exports during a season. *Share of inputs from VI suppliers* is the share of a firm's (or plant's) inputs that come from VI suppliers during a season. Steel boats tend to be bigger, better suited for industrial fishing, and are subject to different regulations. High capacity boats are boats whose hold capacity is in the upper quartile of the distribution. Boats without integrated cooling system use ice to keep fish fresh. *High technology share of capacity* controls for the share of the firm's total processing capacity (measured in metric tons per hour and averaged across all active plants within the firm) that uses steam drying technology. *Share of inputs from relational suppliers* is the share of a firm's inputs that come from suppliers under a relational contract during a season. In Panel A, we define an independent boat as being under a relational contract if the boat delivers more than 80% of its offloads (75th percentile) to the same fishmeal firm for 2 consecutive fishing seasons. In Panel B, we define an independent boat as being under a relational contract if the boat interacts more than 20 times (median) with the same firm during a fishing season and so, for at least 3 consecutive fishing seasons. Standard errors clustered at the firm level are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

TABLE A10: SUPPLIER BEHAVIOR AND VERTICAL INTEGRATION - ROBUSTNESS CHECKS

Panel A: Output quality, supplier behavior and vertical integration			
Dep. var:	Log(Quantity supplied)	Log(Max. distance from the plant's port)	Log(Total time spent at sea)
	(1)	(2)	(3)
I[VI × supplies owner firm × Plant producing high quality]	-0.029	-0.140^{***}	-0.036^{***}
	(0.024)	(0.022)	(0.009)
I[VI × supplies owner firm]	Yes	Yes	Yes
I[Plant producing high quality]	Yes	Yes	Yes
Date FEs	Yes	Yes	Yes
Supplier × Plant FEs	Yes	Yes	Yes
N	315 442	137 278	159 724
Panel B: Output quality, vertically integrated share of inputs, and difficult upstream production conditions			
Dep. var:	Log(Quantity supplied)	Log(Max. distance from the plant's port)	Log(Total time spent at sea)
	(1)	(2)	(3)
I[VI × supplies owner firm × Difficult conditions]	0.038	-0.097^{***}	-0.006
	(0.026)	(0.025)	(0.035)
I[VI × supplies owner firm]	Yes	Yes	Yes
I[Difficult conditions]	Yes	Yes	Yes
Date FEs	Yes	Yes	Yes
Supplier × Plant FEs	Yes	Yes	Yes
N	224 901	122 216	142 010

Notes: *Quantity supplied* is the amount of fish the boat delivers to the plant per trip. *Max. distance from the plant's port* is maximum distance a specific boat is observed away from port. *Max. distance from the plant's port* can only be measured if the boat leaves from and arrives at the same port. *Total time at sea* is the amount of time the boat is away from port per trip. I[Boat goes on trip] is the likelihood that the boat goes out fishing on a specific **day**. I[Plant producing high quality] is a dummy equal to one if the plant the supplier delivers to produces only high quality fishmeal. The number of observations varies from one column to the next as GPS variables for on given trip are sometimes missing. I[*Difficult conditions*] is a dummy equal to 1 when the share of good fishing locations [Log(plankton concentration)>0.5] around a specific plant on a specific day is less than 10 percent (this corresponds to the bottom 20th percentile in the distribution of share of good fishing locations in our sample). Standard errors clustered at the boat owner level are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE A11: OUTPUT QUALITY, VERTICALLY INTEGRATED SHARE OF INPUTS, AND DIFFICULT UPSTREAM PRODUCTION CONDITIONS - ROBUSTNESS CHECKS

	Panel A: Plants within a major firm			
Dep. var:	Log(unit price)		Protein content	
	(1)	(2)	(3)	(4)
Share of inputs from VI suppliers	1.338^{**}	0.875	0.107^{**}	0.081^{*}
	(0.656)	(0.607)	(0.044)	(0.041)
Difficult conditions		-2.359^{***}		-0.242^{***}
		(0.836)		(0.060)
Share VI × Difficult conditions		3.213^{***}		0.163^{**}
		(0.686)		(0.070)
Has high technology	Yes	Yes	Yes	Yes
Season FEs	Yes	Yes	Yes	Yes
Plant FEs	Yes	Yes	Yes	Yes
Mean of Dep. Var.	65.8	65.8	7.23	7.23
N	66	66	66	66

	Panel B: All Plants	
Dep. var:	High quality share of production	
	(1)	(2)
Share of inputs from VI suppliers	0.076**	0.076***
	(0.033)	(0.033)
Difficult conditions		-0.027
		(0.046)
Share VI × Difficult conditions		0.080
		(0.059)
Has high technology	No	Yes
Month FEs	Yes	Yes
Plant FEs	Yes	Yes
Mean of Dep. Var.	0.79	0.79
N	1986	1986

Notes: This table is similar to Table 7 but the unit observation is the plant instead of the firm × level. Panel B focuses on a single firm for which more detailed plant level measures are available at the season level. Panel B uses data from all plants, at the month level, but uses a dichotomous variable for quality. *Log(unit price)* is the log of the quantity weighted average unit price of exports during a season. *Protein content* is the quantity weighted average of a measure of quality inferred with a database that provides weekly prices by quality. *Has high technology* controls for whether a plant is equipped or not with the steam drying technology. *Share of inputs from VI suppliers* is the share of a plant's inputs that come from VI suppliers in a given season. I[*Difficult conditions*] is a dummy equal to 1 when the share of good fishing locations [Log(plankton concentration)>0.5] around a specific plant on a specific day is less than 5 percent (this corresponds to the bottom 10th percentile in the distribution of share of good fishing locations in our sample). This dummy is defined at the port-day level, while the regressions are at the firm-season level, so the dummy variable is averaged by firm-season to construct *Difficult conditions*. It can then be interpreted as the share of days when the conditions are difficult for a specific firm during a production season. The variable is normalized to a mean equal to 0 in our sample so that the first row of this table can be interpreted as the correlation between the *Share of inputs from VI suppliers* and quality. Panel B includes standard errors clustered at the firm level in parentheses. Panel A includes robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE A12: DIFFICULT UPSTREAM PRODUCTION CONDITIONS - ROBUSTNESS CHECKS 2

Panel A: Output quality, vertically integrated share of inputs, and difficult upstream production conditions

Dep. var:	Protein content		Log(unit price)	
	(1)	(2)	(3)	(4)
Share of inputs from VI suppliers	1.313***	1.183***	0.137*	0.116*
	(0.407)	(0.379)	(0.071)	(0.062)
Difficult conditions		−1.127		−0.181*
		(0.847)		(0.092)
Share VI × Difficult conditions		1.538**		0.236***
		(0.713)		(0.072)
High technology share of capacity	Yes	Yes	Yes	Yes
Season FEs	Yes	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes	Yes
Mean of Dep. Var.	65.4	65.4	7.20	7.20
N	179	179	179	179

Panel B: Supplier behavior, vertical integration and difficult upstream production conditions

Dep. var:	Log(Quantity fished)	Log(Maximum Distance from the Port)	Log(Total time spent at sea)
	(1)	(2)	(3)
I[VI × supplies owner firm] ×I[Not difficult conditions]	−0.091***	−0.037	−0.017
	(0.032)	(0.023)	(0.017)
I[VI × supplies owner firm] ×I[Difficult conditions]	−0.033	−0.252*	−0.244***
	(0.095)	(0.143)	(0.076)
Date FEs	Yes	Yes	Yes
Supplier × Plant × Difficult conditions FEs	Yes	Yes	Yes
N	223 316	121 164	140 911

Notes: This Table is similar to Table 7 and Table 8 but uses another definition of *difficult production conditions*. I[*Difficult conditions*] is here a dummy equal to 1 when the share of good fishing locations [Log(plankton concentration)>0] around a specific plant on a specific day is less than the bottom 15th percentile in the distribution of share of good fishing locations in our sample. This dummy is defined at the port-day level, while the regressions are at the firm-season level, so the dummy variable is averaged by firm-season to construct *Difficult conditions* in Panel A. It can then be interpreted as the share of days when the conditions are difficult for a specific firm during a production season. The variable is normalized to a mean equal to 0 in our sample so that the first row of this table can be interpreted as the correlation between the *Share of inputs from VI suppliers* and quality. *Protein content* is the quantity weighted average of a measure of quality inferred from a database that provides weekly prices by quality. *Log(unit price)* is the log of the quantity weighted average unit price of exports during a season. *Share of inputs from VI suppliers* is the share of a firm's (or plant's) inputs that come from VI suppliers during a season. Steel boats tend to be bigger, better suited for industrial fishing, and are subject to different regulations. High capacity boats are boats whose hold capacity is in the upper quartile of the distribution. Boats without integrated cooling system use ice to keep fish fresh. *High technology share of capacity* controls for the share of the firm's total processing capacity (measured in metric tons per hour and averaged across all active plants within the firm) that uses steam drying technology. In Panel B, *Quantity supplied* is the amount of fish the supplier delivers to the plant per trip. *Max. distance from the plant's port* is maximum distance a specific boat is observed from port during a trip. *Total time at sea* is the amount of time the supplier is away from port per trip. The number of observations varies from one column to the next as GPS variables for on given trip are sometimes missing. *Max. distance from the plant's port* can only be measured if the boat leaves from and arrives at the same port. Standard errors clustered at the firm level in Panel A, and at the boat owner level in Panel B, are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

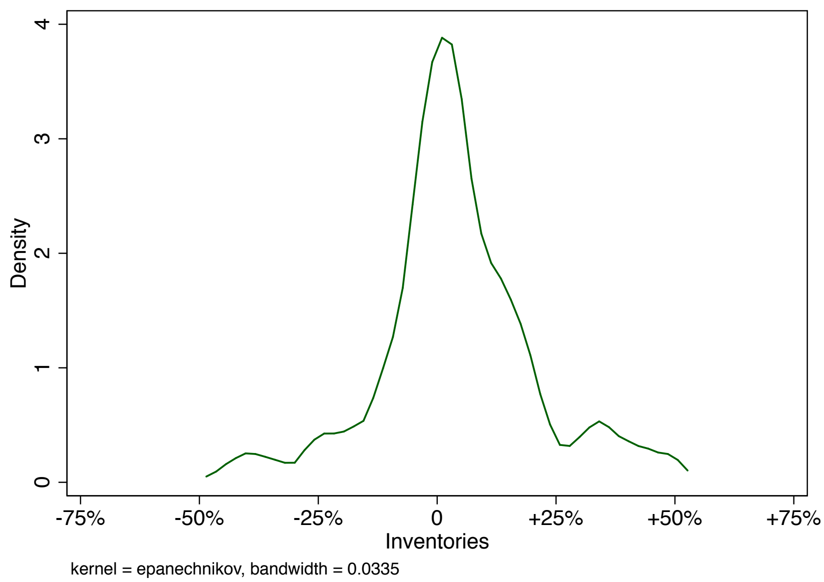
TABLE A13: COUNTRIES' OUTPUT QUALITY AND VERTICAL INTEGRATION IN EXPORT MANUFACTURING

Dep. var:	Log(unit value) - Residuals from Product × Year FEs and Country FEs
	(1)
Related party share of imports - Residuals from Product × Year FEs and Country FEs	0.038^{***}
	(0.007)
N	208 024

Notes: In this table, the dependent variable is ε_{cpt} from the regression log(unit value)$_{cpt} = \alpha_{pt} + \gamma_c + \varepsilon_{cpt}$, where log(unit value)$_{cpt}$ is the average log unit value of products exported from country c, of HS6 code p, in year t to the U.S.; α_{pt} is a product×year fixed effect; and γ_c is an origin country fixed effect. This regression is estimated using COMTRADE data from BACI (See **??**. The independent variable is υ_{cpt} from the regression Related party share of U.S. imports$_{cpt} = \beta_{pt} + \delta_c + \upsilon_{cpt}$, where Related party share of U.S. imports$_{cpt}$ is the share of products exported from country c, of NAICS code p, in year t to the U.S. that are imported by related parties (usually other units of the same firm (Ruhl, 2015)); β_{pt} is a product×year fixed effect; and δ_c is an origin country fixed effect. Related party share of U.S. imports$_{cpt}$ is constructed using data from the U.S. Census Bureau. Because the product level c (HS6) for the unit value residual is different from the product level p (NAICS) from the share of related party imports residuals, we compute the value weighted unit value residual at the p (NAICS) level using a HS6-NAICS conversion table. This regression includes data from 2005 to 2014. Robust standard errors in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

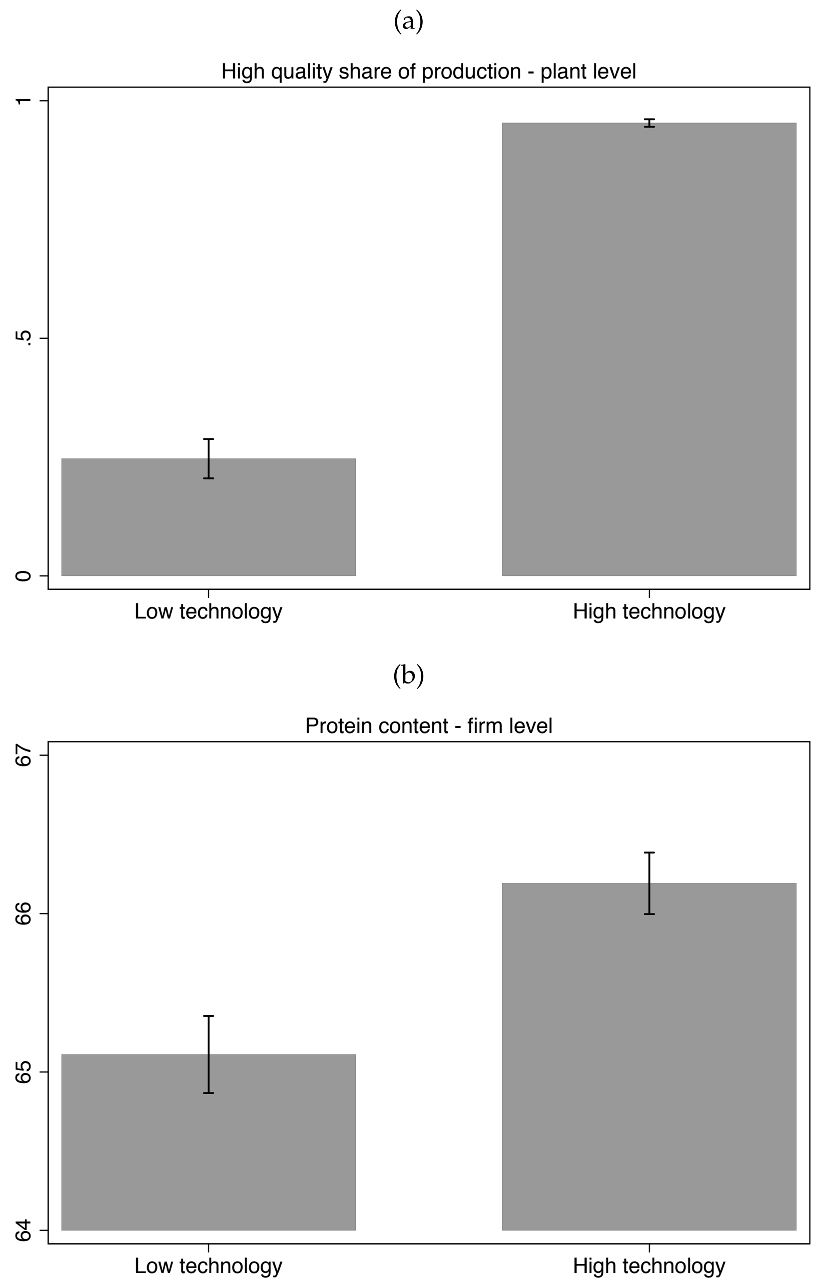
Appendix figures

FIGURE A1: DENSITY OF INVENTORIES



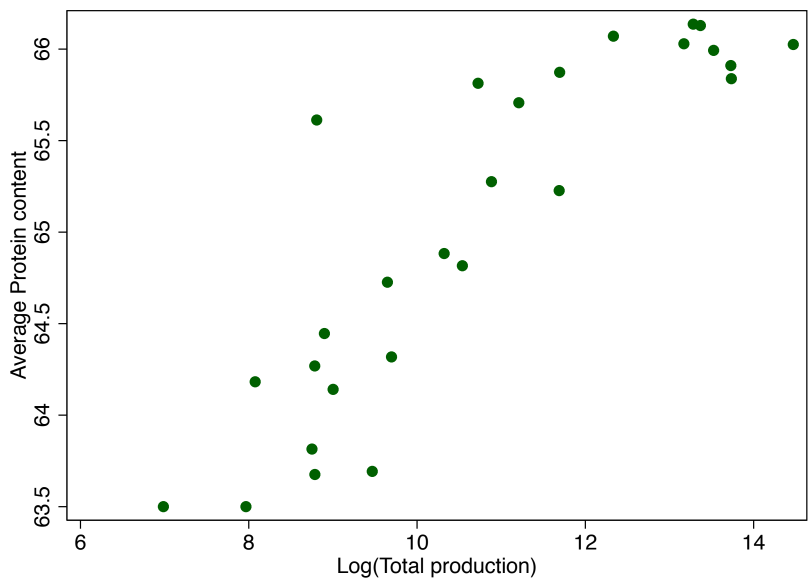
Notes: Kernel density of estimated inventories. Inventories are defined as the ratio of (Total Production - Total Exports) to Total Production, where Total Production is a firm's production during a given production season and Total Exports are the sum of exports that are shipped during the production season and the period directly following the relevant production season (before the next production season starts).

FIGURE A2: PLANT TECHNOLOGY AND OUTPUT QUALITY



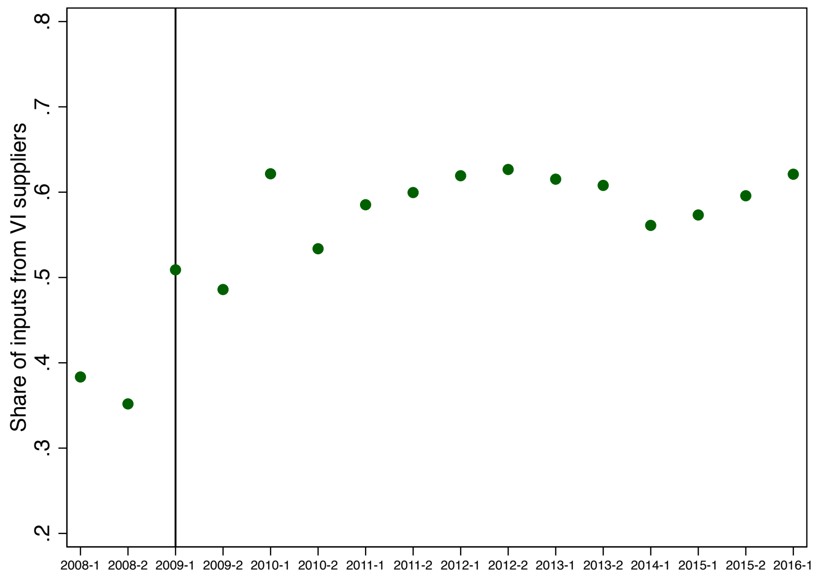
Notes: Panel (a) shows the high quality share of production for plants with high technology (as defined in Section **??**) and plants that only have low technology. Panel (b) shows the average protein content (quality grade) for high and low technology firms. High technology firms are firms for which the high technology share of total capacity is above the sample median.

FIGURE A3: AVERAGE OUTPUT QUALITY AND FIRM SIZE



Notes: Each dot represents one fishmeal firm in our sample. Total production is the total weight of fishmeal the firm produced during our data period and average protein content is the quantity weighted average protein content of the firm's fishmeal exports.

FIGURE A4: EVOLUTION OF THE VERTICALLY INTEGRATED SHARE OF INPUTS INDUSTRY-WIDE



Notes: This graph shoes the evolution of the Peruvian fishmeal industry's share of inputs from integrated suppliers by production season. For every year, -1 is the first production season in the calendar year, in general from April to July, and -2 is the second production season, in general from November to January.