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

Christopher Hansman
Imperial College London

Jonas Hjort
Columbia University
& CEPR & NBER

Gianmarco León-Ciliotta
Universitat Pompeu Fabra
& BGSE & IPEG & CEPR

Matthieu Teachout
International Growth Centre

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Abstract

We study the relationship between firms' output quality and organizational structure. Using data on the production and transaction chain that makes up Peruvian fishmeal manufacturing, we establish three results. First, firms integrate suppliers when the quality premium rises for exogenous reasons. Second, suppliers change their behavior to better maintain input quality when vertically integrated. Third, firms produce a higher *share* of high-quality output when weather and supplier availability shocks shift them into using integrated suppliers. Overall, our results indicate that quality upgrading is an important motive for integrating suppliers facing a quantity-quality trade-off, as classical theories of the firm predict.

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Winner of the 2018 Oliver Williamson Award for best paper presented at the Society of Institutional and Organizational Economics' annual conference. c.hansman@imperial.ac.uk, hjort@columbia.edu, gianmarco.leon@upf.edu, mrt2138@columbia.edu. We are especially grateful to Editor Chad Syverson, three anonymous referees, Francesco Amodio, Bob Gibbons, Amit Khandelwal, Kaivan Munshi, Eric Verhoogen, and Chris Woodruff for suggestions that significantly improved the paper. We also thank Charles Angelucci, John Asker, David Atkin, Jie Bai, Jing Cai, Lorenzo Casaburi, Wouter Dessein, Dave Donaldson, Marina Halac, Oliver Hart, Rocco Macchiavello, Ameet Morjaria, Andrea Prat, John Van Reenen, Xiao Yu Wang, and Daniel Wolfenzon for comments and advice; seminar participants at Cambridge, Columbia, LSE, MIT, NBER, UPF, Zurich, the Markets and Organizations in Emerging Economies Conference, the Society of Institutional and Organizational Economics, the Summer School in Development Economics (SSDEV), and the IGC/Stanford SCID conference on Firms, Trade and Development; Patrick Kennedy, Leonor Lamas, and Sebastián Sardón for great research assistance and field work; and the executives in the Peruvian fishmeal manufacturing industry we interviewed for their time. The Peruvian Ministry of Production, Cesar Casahuamán, and IFFO (in particular Enrico Bachis and Jorge Mora) 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 (SEV2015-00563), grant ECO2011-25272 and RYC-2017-23172.

1 Introduction

Why do so many of our economic transactions occur within firm boundaries (Coase, 1937; Gibbons, 2005a; Lafontaine & Slade, 2007)? Vertical integration occurs for many different reasons, and motives vary by context.[1] However, as global incomes rise and barriers to trade fall, one potential motive has gained increased relevance: firms integrating in order to improve product quality. Access to wealthier, quality-sensitive markets brings rising returns to output quality,[2] but producing high quality output typically requires high quality inputs (see e.g. Kugler & Verhoogen, 2012; Halpern *et al.* , 2015; Amodio & Martinez-Carrasco, 2018). Because input quality is often hard for firms to measure and contract over (Gibbons, 2005a; Lafontaine & Slade, 2007)—especially where institutions are weak (Woodruff, 2002; Nunn, 2007)—organizational structure may play a crucial role in firms' ability to meet demand for quality.

In this paper we test the hypothesis that firms vertically integrate in order to produce higher quality products. This conjecture is inspired by classical theories characterizing how firm boundaries are expected to respond to output objectives (Baker *et al.* , 2001, 2002; Gibbons, 2005a,b) when suppliers multitask (Holmstrom & Milgrom, 1991). However, given the rarity of data on product quality and internal firm structure, and the challenges of isolating firm strategy from confounding factors, causal evidence on the extent to which firms change their organizational structure to upgrade quality has remained elusive.

The context we study, the Peruvian fishmeal industry, enables progress. The structure of the sector is simple. Independent and integrated suppliers deliver inputs of hard-to-observe quality to manufacturers. Manufacturers convert these inputs into a vertically differentiated but otherwise homogeneous product.[3] Uniquely rich data on the sector's entire chain of production is available, including within-firm transactions and direct measures of output quality. Finally, there is substantial—and plausibly exogenous—variation in the *quality premium*, the price differential between high and low quality fishmeal. This allows us to isolate explicit strategic responses to incentives to quality upgrade.

Our analysis proceeds in four steps. We first present a simple theoretical framework that describes how and why a firm's choice of organizational structure may depend on its output quality objectives. We then ask if quality-upgrading motives are—empirically—a direct determinant of integration decisions; that is, whether a manufacturer is more likely to integrate its suppliers when its returns to shifting from low to high quality production are higher. Next, we explore the mechanisms through which output quality objectives may impact integration decisions. We estimate how organizational structure affects supplier behavior, focusing particularly on "switchers"—suppliers who supply the same plant before and after being integrated (or sold). To conclude, we investigate whether integration ultimately raises output quality.

There are several reasons why unique data is available on the fishmeal industry in Peru. The regulatory authorities record all transactions between fishmeal plants and suppliers, and require firms to report each of their plants' production of fishmeal in the "prime" (high) quality and the "fair average" (low) quality range

[1] Empirical work on the causes and consequences of firms' choice of organizational structure in developing countries began in earnest with Woodruff (2002). Gibbons (2005a); Lafontaine & Slade (2007); Bresnahan & Levin (2013) provide excellent overviews of the broader literature on firms' structure.

[2] See e.g. Sutton (1991, 1998); Hallak (2006); Verhoogen (2008); Manova & Zhang (2012); Atkin *et al.* (2017); Bastos *et al.* (2018).

[3] Fishmeal is a brown powder made by burning or steaming fish, and mostly used as animal feed. Peru's fishmeal industry accounts for around 3 percent of GDP (Paredes & Gutierrez, 2008; De La Puente *et al.* , 2011). Price differentials across shipments of a given quality level in a given time period are negligible (see Sub-section 2.2). 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).

each month, providing a direct measure of quality.[4] We can link these input and output quantities to all export transactions, which are recorded in customs data. Furthermore, researchers—but not manufacturers—directly observe both independent and integrated suppliers' behavior because fishing boats are required to transmit GPS signals to the regulatory authorities.[5] In combination, these data sources allow us to track the flow of goods—from suppliers, to manufacturers, to foreign buyers—and provide the measures of output quality and firm-supplier transactions necessary to establish a correlation between the quality of a firm's output and the organizational structure of its production chain.

However, even if documented with ideal data, such a correlation may reflect third factors rather than an explicit organizational choice made *in order to* "climb" the quality ladder. It could be, for example, that productivity or demand affect both firms' choice of structure and products produced without the two being directly related. It could also be that firms integrate for reasons other than quality—for example to assure their own or restrict competitors' general access to inputs—but in the process coincidentally produce higher quality output. To identify a direct relationship between output quality objectives and integration, exogenous variation in incentives to upgrade quality—the quality premium—that firms are *differentially exposed to* is needed.

The quality premium facing Peruvian fishmeal firms varies considerably during the period we study. This allows us to test our causal hypothesis. Our empirical strategy exploits season-to-season variation in the quality premium that is due to fluctuations in the regulatory fishing quotas of *countries other than Peru* that produce high quality fishmeal. We construct an instrument for the quality premium, and test whether these fluctuations affect firms differently depending on their scope for upgrading quality.

We begin our analysis with a stylized model, which demonstrates how characteristics of the Peruvian fishmeal industry map directly to the existing theoretical work we build on. Fishmeal manufacturers face two important contracting challenges. First, the quality of the product's primary input—fish—is difficult to observe and, because of its perishable nature, even harder to contract upon. Second, the presence of outside options—other fishmeal firms who may value input quality less—complicates controlling the incentives of an independent supplier (see also McMillan & Woodruff, 1999).[6] Holmstrom & Milgrom (1991) elegantly demonstrate how, when suppliers face a trade-off between producing inputs of high quality or in high volumes, weakening incentives over easier-to-measure *quantity* may be necessary to ensure that suppliers do not neglect *quality* (see also Holmstrom & Tirole, 1991; Holmstrom, 1999). In many situations, the best or only way to do so may be to bring the suppliers inside the firm (Baker *et al.* , 2001, 2002; Gibbons, 2005a,b).

To take these textbook theoretical insights to the data, we first demonstrate that output quality is in fact significantly positively correlated with integration. Our primary measure of quality is the share of a firm's output that is of high quality grade—which we directly observe in production data. We also consider a fine-

[4]See Goldberg & Pavcnik (2007); Khandelwal (2010); Hallak & Schott (2011) for discussion of the indirect quality proxies used in the existing literature, which risk conflating quality with mark-ups and horizontal differentiation, and Atkin *et al.* (2017) for an example of direct measures of quality.

[5]The regulators do not allow manufacturers to access data on the behavior of independent suppliers. This is the primary reason why manufacturers and independent suppliers cannot contract over GPS-measured actions.

[6]It is in theory possible to imperfectly measure fish quality with chemical tests. As discussed in Section 2, industry insiders informed us that such tests were much too expensive and impractical to use during our data period. Alternatively, manufacturers and their suppliers could attempt to contract on plants' *output* quality. This would be difficult because of noise—input from multiple suppliers is, for technological reasons, typically used in a given batch of fishmeal, and other hard-to-measure exogenous factors also influence output quality realizations—and, more importantly, because outside inspectors would need to be able to determine if low output quality was due to poor input quality or actions taken by the fishmeal plant itself during the production process. The dynamic version of our model in Appendix C demonstrates why the presence of other fishmeal manufacturers who value input quality less can make repeated interactions solutions to these challenges infeasible.

grained (but not-directly-observed) measure of the average quality grade of a firm's output. Similarly, we consider two different measures of vertical integration, one based on *use* of integrated versus independent suppliers and the other on supplier ownership. The relationship we establish holds across each of our measures of a firm's output quality and each of our measures of a firm's organizational structure.[7]

We then proceed to our central empirical analysis, which consists of three key pieces of evidence. The first of these—and this paper's main finding—shows evidence that vertical integration is used by firms *as a strategy* for increasing output quality. To demonstrate this, we develop an IV for firm-specific incentives to upgrade quality. We instrument for the quality premium—the difference between the price of high and low quality grades—using the regulatory fishing quotas of other top exporters. Because the other top exporters specialize in high quality grades, and because their production quantities are driven by country-specific regulatory fishing quotas, these quotas generate plausibly exogenous variation in the premium. We test if this variation *differentially* impacts Peruvian firms' integration decisions depending on their firm-specific scope for upgrading quality. Firms that are already producing mostly high quality output have little scope to improve quality further and are hence unlikely to respond strategically to an increase in the quality premium. Conversely, firms producing mostly low quality output have significant scope to upgrade. Thus, if firms use integration as a strategy for upgrading quality, then firms producing primarily or exclusively high quality output will face weaker incentives to integrate when the quality premium rises.[8]

We find that Peruvian manufacturers integrate when their incentives to upgrade quality rise, and vice versa. *The industry as a whole* integrates when the quality premium increases for exogenous reasons, and the integration response is stronger for firms with greater scope for upgrading quality.[9] Firms adjust the fraction of their inputs that are sourced from integrated suppliers in response to exogenous variation in the quality premium almost entirely via the extensive margin of "Share VI", i.e., by acquiring and selling suppliers. In an alternative approach shown in the Appendix, we exploit a different form of variation to show that firms similarly integrate when faced with greater firm-specific relative *demand* for high quality output. Finally, and crucially, we show that firms' organizational response to the quality premium does not reflect associated income shocks or general incentives to expand production of any-quality fishmeal: firms *do not* integrate suppliers when faced with higher average prices.

This first piece of evidence is hard to reconcile with alternative theories in which higher output quality is an unforeseen by-product of vertical integration driven by other motives and with stories wherein organizational structure and output quality are not causally linked in the "minds" of firms. Several of the most prominent, *specific* alternative explanations—such as firms integrating suppliers for general supply assur-

[7]Our primary measure of integration is the fraction of inputs that are sourced from integrated suppliers ("Share VI")—a measure that is motivated by our hypothesis that the characteristics of the inputs actually *delivered* by a supplier changes with integration so that integration and output quality are causally linked via firms' (and individual plants') *production* process. (On *use* of integrated versus independent suppliers, see also, among others, Baker & Hubbard (2003); Atalay *et al.* (2014); Breza & Liberman (2017)). Alternatively, we also consider the number of suppliers owned. Note that, in our setting, since boats' total seasonal catch is governed by a quota—and boats almost always exhaust their quota over the course of a season—Peruvian fishmeal manufacturers can generally increase the total amount of inputs they obtain from integrated suppliers in a given production season only by acquiring suppliers (see Section 2).

[8]A potential criticism of this argument is that firm-specific scope for quality upgrading might also correlate with some unobservable related to the marginal cost of integration and/or quality upgrading. The most natural forms of such arguments—that firms producing high quality output (a) have low marginal costs of further upgrading and are also more likely to integrate in general, or (b) have low marginal costs of integration and are also more likely to upgrade in general—predict the opposite of our findings. Furthermore, as our primary measure of quality is a share (rather than a level), arguments such as (a) cannot hold for firms that are already producing exclusively high quality, as they mechanically have no scope to improve further. Our results considering these firms are similar.

[9]The long-term trend is towards more integration in the Peruvian fishmeal industry, and the long-term trends in demand for quality and average output quality in Peru are also positive. These broad patterns are consistent with our hypothesis. However, it is higher frequency variation *around* the long-term trends that we exploit to *test* our hypothesis. For example, we also observe de-integration during our data period—sales of boats from fishmeal firms to independent co-ops or captains, and from one fishmeal firm to another.

ance reasons but coincidentally achieving higher quality in the process, and foreclosure motivations—are also inconsistent with other features of the context we study and auxiliary findings.[10] While we cannot rule out that alternative mechanisms also play a role, our results indicate that quality upgrading itself is an important motive for integrating suppliers.

Next we explore *why* firms use integration as a strategy for upgrading quality. Our second key piece of evidence shows that integration changes suppliers' behavior, causing them to shift towards quality-increasing actions. We proxy for actions that increase input quality—i.e., fish freshness (FAO, 1986)[11]—using GPS-based measures. We show that—as the managers in the industry we interviewed reported to us[12]—a *given supplier supplying a given plant* delivers lower total quantities, but inputs whose quality has been better maintained, when integrated with the plant. We also show that, in the context we study, it is integration *per se*—not repeated interactions—that influences a supplier's quantity-versus-quality behavior. This result is consistent with a dynamic version of our model—which, along with the result, is shown in Appendix C—and with the fact that suppliers that de-integrate from a firm/plant supply that firm/plant almost as often after the change in status. Finally, we consider the possibility that integration affects behavior not via a supplier's quantity-quality trade-off, but instead via associated knowledge transfers, of the form that Atalay *et al.* (2014) convincingly show occur in the U.S. post-integration. We find that a given supplier behaves "as an integrated supplier" only when supplying its owner firm and not when owned by one firm *but supplying another*. Reconciling this finding with knowledge transfer theories would require such knowledge transfers to be useful only when supplying the parent firm. We ultimately cannot rule out that other incentives emanating from organizational structure itself than those our model focuses on also help explain the impact of integration on supplier behavior, but our *third* piece of evidence suggests that any such alternative incentives would need to ultimately benefit downstream output quality.

Our third piece of evidence indicates that vertical integration in fact increases output quality, as the managers in the industry we interviewed reported to us. (In the words of the Managing Director of Pesquera Diamante, Peru's third largest fishmeal company: "Around 80 percent of my company's fishmeal is high-quality. If all my inputs came from integrated boats, around 95 percent of my fishmeal output would be of high-quality." (Authors' translation).) We first show that the firm level relationship between the share of inputs coming from integrated suppliers—Share VI—and output quality holds also at the individual plant level, including *within* firms. We then instrument for a plant's Share VI using both a leave-firm-supplied-out measure of the local presence of a particular type of supplier that is prohibited by regulation from being integrated[13], and weather shocks that differentially affect integrated and independent suppliers'

[10] We show that (i) Peruvian fishmeal manufacturers appear to achieve general supply assurance primarily through repeated interactions with independent suppliers (see also Martinez-Carrasco, 2017)—the quantity supplied by a given supplier to a given firm is in fact *lower* after integration (/before de-integration)—and (ii) repeated interactions with suppliers do not enable firms to produce higher quality output. Similarly, the relationship between output quality and integration holds when we control for a firm's share of the industry's total production, in contrast to what traditional "foreclosure" theories would predict.

[11] "Freshness of raw material is important in its effect on the quality of the protein in [quality of] the end product [fishmeal]. The importance of minimizing the time between catching fish and processing, and of keeping the fish at low temperatures by icing [which reduces the amount of fish a boat can fit], has already been mentioned" (FAO, 1986, sub-section 10.1.2).

[12] In the words of a prominent executive of Peru's National Fisheries Society: "as a consequence of integration, they must adopt my rules. Things like saying, 'hey, you must offload raw 24 hours after having caught it, at the maximum."' (Authors' translation).

[13] The presence of such suppliers fluctuates due to natural variation in fish density, weather, and decisions made by their captains. The logic behind this first instrument for Share VI is simply that a plant—holding fixed output quality objectives—will be forced to source a higher share of its inputs from integrated suppliers when there happens to be a local scarcity of independent suppliers. Plausible arguments against the exclusion restriction underlying our interpretation of the results from this first IV approach would arguably require a positive sign on the first stage (negative correlation between the use of independent suppliers by different plants in a locality), a negative sign on the second stage (use of independent suppliers increasing output quality), and/or a time-varying, location level component of output quality (that goes beyond the presence of independent suppliers)—none of which we find.

whereabouts. The IV estimates are similar to each other, but somewhat larger than OLS estimates.

When viewed through the lens of our model, the three key pieces of evidence we present each follow logically from each other. We conclude that aspiring to produce higher quality products can motivate firms to vertically integrate, and that the reason appears to be that integration changes supplier behavior in a way that increases output quality. Because input quality is so frequently difficult to observe (and hence incentivize), the challenges we describe—while far from universal—are likely typical of industries producing vertically differentiated output, particularly in settings where contracts are difficult to enforce.[14]

Our study bridges and advances the literatures on the boundaries of the firm and quality upgrading. We make three contributions to the former. First, we identify an overlooked motivation for vertical integration. By showing that firms vertically integrate in order to raise output quality, we advance the body of work on the *causes* of organizational form (for seminal empirical work, see Hart *et al.* (1997); Baker & Hubbard (2003, 2004); Forbes & Lederman (2009)). Existing studies convincingly demonstrate how firms change their relative use of integrated suppliers in response to changes in e.g. available contracts (Breza & Liberman, 2017) or monitoring technology (Baker & Hubbard, 2003). We instead study how firms change their organizational structure when their output *objectives* change.[15]

Second, and building on earlier studies of the behavior of integrated and independent suppliers (Mullainathan & Sharfstein, 2001; Baker & Hubbard, 2003, 2004; Macchiavello & Miquel-Florensa, 2016), we provide what to our knowledge is the first evidence on how integration changes the quality-oriented behavior of a given supplier supplying a given firm. To do so we follow Atalay *et al.* (2014) and exploit changes in integration within supplier-firm pairs.

Finally, we show evidence that vertically integrating raises output quality, which to our knowledge has not been done before. The one-dimensional nature of quality differentiation in our setting allows us to document this.[16] In general, there is little existing evidence on causal consequences of organizational structure for firm performance (see Gibbons & Roberts (2013), and Forbes & Lederman (2010) for a notable exception). Our results also imply that using *independent* suppliers is often efficient for producing output in *high volumes* rather than of high quality (see also Kosová *et al.* , 2013). An especially unusual aspect of this paper is that the data and variation we exploit allow us to identify *both* the effectiveness of particular firm strategy and corresponding determinants of its use. We can therefore show that Peruvian fishmeal manufacturers vertically integrate when quality objectives indicate that they *should* do so.

Both the friction—imperfect contracting over input quality—and the firm objective—producing high quality output—we focus on are especially relevant for poorer countries attempting to help meet growing global demand for quality. This connects our paper with a smaller empirical literature on the causes and consequences of firms' choice of organizational structure in the developing world that began with Woodruff (2002)'s landmark study (see also Natividad, 2014; Macchiavello & Miquel-Florensa, 2016; Martinez-Carrasco,

[14]There is a robust relationship between countries' input-output structure and their level of contract enforcement (Nunn, 2007; Boehm, 2018), and vertical integration is more common in developing countries (Acemoglu *et al.* , 2005; Macchiavello, 2011).

[15]In a superficial sense, our finding that higher average fishmeal prices do not lead to more integration in the Peruvian fishmeal industry contrasts with the innovative work of Alfaro *et al.* (2016). We see our results as largely consistent with and complementary to theirs, however. Both their analysis and ours emphasize the impact of prices in the context of certain goods—in our case high quality products—where integration generates a gain in efficiency. We highlight that this efficiency gain is not generic, but rather depends on firms' quality objectives, while they emphasize that efficiency gains can also depend on the need to coordinate production stages.

[16]In settings where product differentiation is multidimensional, an analysis like ours would be difficult. Like this paper, the pioneering study by Forbes & Lederman (2010) exploits exogenous drivers of use of integrated suppliers, showing that routes airlines self-manage have fewer delays/cancellations (see also Gil *et al.* , 2016; Gil & Kim, 2016). Other important evidence on the *consequences* of organizational structure includes, among others, Novak & Stern (2008); Gil (2009).

2017).[17]

The literature on quality upgrading is larger. It is now well-documented that producers of high quality goods use high quality inputs (Kugler & Verhoogen, 2012; Halpern *et al.* , 2015; Amodio & Martinez-Carrasco, 2018; Bastos *et al.* , 2018), skilled workers (Verhoogen, 2008; Frías *et al.* , 2009; Brambilla *et al.* , 2012; Brambilla & Porto, 2016; Brambilla *et al.* , 2019), and export to richer destinations (Hallak, 2006; Verhoogen, 2008; Manova & Zhang, 2012; Atkin *et al.* , 2017; Bastos *et al.* , 2018). Firms with such a profile tend on average to be bigger, more productive, based in richer countries themselves, and to face foreign competition in low-quality segments (Schott, 2004; Hummels & Klenow, 2005; Baldwin & Harrigan, 2011; Johnson, 2012; Medina, 2017). We provide the first evidence linking quality upgrading to the boundaries of the firm.

2 Background on Peru's Fishmeal Manufacturing Sector

In this section we provide an overview of Peru's fishmeal manufacturing sector. We argue that three features are particularly salient for firms attempting to source high quality inputs: input quantity is measurable at the time of delivery, but input quality is not, and formal contracts appear to be difficult to write.

2.1 Sector profile

Fishmeal is a brown powder made by burning or steaming fish (in Peru, the anchoveta), and is primarily used as feed for agriculture and aquaculture. Peru makes up around 30 percent of the world's fishmeal exports. During our data period, 2009 to 2016, around 95 percent of the country'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).

Fishmeal is produced in manufacturing plants located along the coast of Peru, of which there were 94 in 2009. These plants were in turn owned by 37 firms. The median number of plants per firm is two during our data period, while the 25th and 75th percentiles are one and five respectively. There is heterogeneity in processing capacity, technology, and the share of production that is of high quality grade across both firms and individual plants in our sample. Firms differ considerably in their average number of export transactions per season, and in the size and value of their shipments. As seen in Appendix Figure A1, firm size correlates positively with average quality grade produced.

Plants receive inputs of raw fish from their suppliers. The suppliers are larger steel boats—which may be independent or owned by the firm that owns the plant—and smaller wooden boats. Regulations prohibit fishmeal firms from owning wooden boats. There are on average 812 (wooden and steel) boats *active* in a given 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 away from the port of delivery (s.d. = 46 kilometers) on average. Changes in installed technology

[17] Woodruff finds that forward integration is less common in the Mexican footwear industry when non-contractible investment by retailers is important, as the property rights framework predicts (Grossman & Hart, 1986; Hart & Moore, 1990). Macchiavello & Miquel-Florensa (2016) convincingly show how supply assurance motives influence organizational structure 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 organizational structure in the Peruvian fishmeal industry. He focuses on an earlier period when an unusual regulatory system—industry-wide fishing quotas—generated common pool incentives famously overshadowing other forms of supplier/plant incentives (see e.g. Tveteras *et al.* , 2011), which lead to an "Olympic race" for fish.

are observed in our data but rare both for boats and plants. Table 1 shows summary statistics, providing further detail on the sector.

Since 2009, boats in Peru have operated under Individual Transferable Quotas (ITQs), a common resource management system used in fisheries and natural resource sectors worldwide. Individual boats are assigned a share of an industry-wide quota. We limit our analysis to the time period after ITQs were implemented to avoid any potential changes in quality production or integration driven by the quota system. Quota-transfer is unlikely to explain firms' response to the time-varying and firm-specific quality upgrading incentives we focus on.

The long-term trend is towards more integration in the Peruvian fishmeal industry, and the long-term trends in demand for quality and average output quality in Peru are also positive. These broad patterns are consistent with our hypothesis. However, it is higher frequency variation *around* the long-term trends that we exploit to *test* our hypothesis. For example, we also observe de-integration during our data period—sales of boats from fishmeal firms to independent co-ops or captains, and from one fishmeal firm to another.

2.2 Product differentiation and quality

An important feature of fishmeal is that *output* quality is effectively captured by a single—measurable—dimension: protein content. Batches with protein content above a specified percentage are labeled "prime" quality, and plants report 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, highlighting the horizontal homogeneity of the product.

Fishmeal's protein content depends crucially on input characteristics, namely the freshness and integrity of the raw fish that boats deliver (see e.g. FAO, 1986). Freshness and integrity of the fish at the time of delivery in turn depends on choices made by the boat's captain before and during a trip, such as the amount of ice brought on board, the amount of fished packed on board, how tightly fish is packed, and the time spent between a catch and delivery to a plant (FAO, 1986). Because of the relationship between freshness and output quality, fish is processed as soon as possible after offload.

While it is easy to weigh and determine the quantity of fish a boat delivers, it is difficult to quantify or measure fish freshness directly. In theory, chemical tests of total volatile nitrogen content can be used to do so (imperfectly), but the managers in the industry we interviewed reported that such tests were too costly and time-consuming to be usable in Peru during our data period. In addition to the fixed cost of (the human and physical capital required for) adoption, this was due to high marginal cost of use and the value lost if fish was not processed immediately after offload. Footnote 6 discusses the extent to which input quality can be inferred from output quality post-production.

After offload, the fish is weighed, cleaned, and converted to fishmeal using one of two technologies: steam drying (hereinafter "High technology") or exposing the fish directly to heat (hereinafter "Low technology"). The technology used can matter for the protein content achieved.

Peru allows anchovy fishing for fishmeal production during two seasons each year and because of the need for fresh fish, fishmeal plants operate only during the fishing seasons. There were thus 14 fishing and fishmeal production seasons during our 2009-2016 study period. In theory fishmeal can be stored for a short period of time, but we find that almost all is sold before the next production season begins, as shown in Appendix Figure A2 and discussed below.

2.3 Organizational structure

Consistent with our hypothesis, both integration and average output quality have slowly increased over time in the Peruvian fishmeal industry. However, these long-term trends are not the source of the relationship between organizational structure and quality upgrading we establish in this paper. This is because our empirical strategy exploits variation *around* the long-term trends for identification.

There is significant buying and selling of suppliers during our sample period. 741 steel boats (which can be vertically integrated) are registered during our data period. As seen in Panel A of Table 2, we observe 317 instances where ownership of a steel boat changes hands. In 103 of these instances, a fishmeal firm acquires a supplier that is initially owned independently, that is, by a co-op or an individual captain. However, we also observe 32 instances where a supplier is sold from a fishmeal firm to an independent buyer, and 50 instances where a supplier is sold from one fishmeal firm to another. On average, 28 percent of the boats that are active in a given season are integrated with a fishmeal firm.

In our data, we observe not only supplier *ownership* but also *deliveries* from integrated and independent suppliers. We can therefore construct a measure of the vertical structure of firms' *production* process, namely the share of inputs coming from integrated suppliers ("Share VI"). Peruvian fishmeal manufacturers' Share VI is on average 43 percent. Firms can generally increase or decrease the maximum amount of inputs they can obtain from integrated suppliers only by buying or selling boats. The reason is that a boat's total catch in a given season is governed by a regulatory quota, and each boat typically exhausts its quota. A firm may vary its Share VI also by increasing or decreasing its use of the firm's integrated suppliers or of independent suppliers. As seen in Appendix Figure A3, and following the trend in ownership, Share VI slowly increased during our data period. In Panel B of Table 2 we show a simple variance decomposition of changes in Share VI (our key dependent variable in Section 5) to highlight the importance of the various margins by which firms may adjust Share VI. We show that 35 percent of the overall variation in changes in Share VI comes from firms buying and selling suppliers; 16 percent from the intensity with which firms make use of their integrated suppliers; and 49 from the intensity with which they make use of independent suppliers.

Importantly for our purposes, Share VI can be defined not just for firms, but also for individual plants within firms. A *plant's* Share VI at a given point in time depends mostly on the organizational structure of the firm the plant belongs to, but there is significant variation across plants within the same firm. This variation depends both on the extent to which firm managers direct integrated suppliers to deliver to one plant over another, and on the presence of independent suppliers near a given plant. The latter varies considerably over time, and depends on variation in weather, fish density, and independent captains' decisions.

Figure 1 shows that integration and de-integration primarily represents a change in the formal status of the relationship between a firm/plant and a supplier engaged in frequent and continuing interactions. The figure displays the fraction of trips suppliers deliver to various firms and plants. The top part of the figure focuses on all boats, while the bottom part of the figure restricts attention to the "switchers" we focus on in our empirical analysis of supplier behavior in Section 6. These switchers—suppliers that get integrated or sold—deliver to the plant (within the acquiring/selling firm) they interact with most frequently around 41 percent of the time *when independent* (i.e. before getting acquired or after getting sold), and around 45 percent of the time when integrated. Similarly, switchers deliver to the acquiring/selling firm around 63 percent of the time when independent and around 81 percent of the time when integrated.[18]

[18]In the top part of the figure, we see that, as a whole, integrated suppliers deliver to the firm they deliver to most often (i.e., the

2.4 Contracting and supplier incentives

There is no centralized spot market for fish purchases: plants are spread out along the coast, both because the fish move around and because of geography's influence on the location of ports. Similarly, the movements of boats are a complex function of fishing conditions, weather (winds, swell, etc), and the captains' incentives. Because of the importance of fish freshness, independent captains typically begin contacting plants over the radio on their way to a port after fishing.

We interviewed fishmeal industry associations, a major company's Managing Director, another major company's Chief Operating Officer, union representatives, 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 there is variation in how the captains and crews of boats owned by fishmeal firms are paid, with many firms using a primarily fixed wage system and some tying fishermen's pay to past weeks' average price of Peruvian fishmeal; and that captains and crews of integrated boats are generally paid as when delivering to the parent firm also when delivering to other firms. Note that both the interviews we conducted and our supply transactions data indicate that partial side-selling by integrated suppliers is not an issue in the industry, primarily due to the significant time commitment necessary to dock and offload.

We are not aware of formal contracts between independent suppliers and firms over when, where, or what quality of fish to deliver. Interviewees reported that payments to independent suppliers—while agreed upon case by case—are typically simply the quantity multiplied by a going price. We use internal data on payments to suppliers from a large firm to confirm this. These indicate that independent suppliers at a given point in time are paid a price per metric ton of fish delivered that is essentially fixed: Port×Date fixed effects explain 99 percent of the price variation across transactions.

Our data on suppliers' behavior—discussed in Section 4—come from a map the regulators update roughly every hour using the GPS signals all boats are required to transmit to authorities while fishing. Firms are allowed to access information on their integrated suppliers' whereabouts if they install the required technology, but not the GPS data of independent suppliers or those owned by other firms. This is a primary reason why manufacturers and independent suppliers cannot contract over GPS-measured actions.

An industry association informed us that almost all contracts between fishmeal firms and their foreign buyers for a given season's production are negotiated either before the season starts, or early in the season. Firms can thus integrate or sell suppliers before a season starts in response to variation in the quality premium and/or high or low demand from particular importer countries.

3 Theoretical Framework

3.1 Description

In this section we present a simple model to highlight how vertical integration may resolve the contracting issues facing downstream firms that aim to produce high quality output. The intuition of the model is based on two insights. First, high powered incentives to produce quantity can lead to actions that are wasteful and even harmful to quality. Second, the open market provides independent suppliers strong incentives

parent firm) about 90 percent of their trips, and the plant they deliver to most often 38 percent of trips. Independent suppliers deliver to the firm they deliver to most often around 65 percent of trips, and the plant they deliver to most often 45 percent of trips.

to produce quantity and, in a setting where contracts are difficult to write, the only way to temper those incentives may be to integrate.

The first point of intuition above—the tradeoff between quality and quantity—is one of the classic examples of the challenges of designing incentives in a multitask environment, and in fact is used by Holmstrom & Milgrom (1991) to motivate their seminal work. This is for the simple reason that input quantity is typically straightforward to measure and reward, while quality is not. As a result, care must be taken not to over-incentivize quantity to the detriment of quality.

Of course, the difficulty of determining quality is somewhat of a stereotype: there are goods for which quality depends on something like strength or size or durability that is just as easy to measure as quantity. However, in our setting, this stereotype seems broadly accurate. While the quantity of fish that suppliers deliver is easily measured, the quality of that fish is difficult to ascertain for a purchasing manager examining several tons of anchoveta.

A few pieces of context are helpful to understand the second point of intuition above. Firstly, it appears that contracts are difficult to write ex-ante: independent suppliers retain their right to deliver their catch where they choose. Additionally, while some firms primarily produce high protein content fishmeal, others primarily produce low quality grades, and hence provide a (presumably less quality sensitive) alternative for suppliers to deliver their catch.[19]

With this in mind, a logic applies that is familiar from the models presented in Baker *et al.* (2001, 2002), based on the notion of integration as asset ownership that follows Grossman & Hart (1986). Even if a firm interested in sourcing high quality inputs has no interest in high volumes, the fact that an independent supplier has the option to sell its inputs to an alternative downstream firm that values quantity creates powerful incentives. The independent supplier will then invest in producing quantity—although it may be wasteful or detrimental—if only to improve its bargaining position with the quality focused firm. By acquiring the supplier, the manufacturer removes this outside option, and hence any incentive for wasteful or harmful investment in quantity. In this sense, integration is valuable precisely because it mutes the power of market incentives, a notion that has been described by Williamson (1971), Holmstrom & Milgrom (1994), and Gibbons (2005a), among others.

3.2 Model details

We consider a static game with two actors: suppliers and high quality firms. Suppliers take costly actions to produce a good that is valuable both to the firms and in an alternative use. They may be integrated or independent. If the suppliers are integrated, the firms that own them have the right to the good after the actions are taken. If the suppliers are independent, they retain the right to the good. They bargain with the high quality firms over whether to deliver the good or consign it to its alternative use.

We assume that suppliers have two potential actions $\{a_1, a_2\}$, with costs $c(a_1, a_2) = \frac{1}{2}a_1^2 + \frac{1}{2}a_2^2$. These actions impact the surplus created by delivering their inputs to a downstream quality focused firm. We denote this surplus by Q, and refer to it as the quality surplus. Suppliers' actions also impact the surplus they receive by delivering the inputs to an alternative—quantity focused—downstream firm. We denote this by P, and refer to it as the quantity surplus. We assume that the good is specific, in the sense that

[19] A question that our model abstracts from is why firms might want to produce different quality levels simultaneously. We return to this question at the end of Section 3.

$Q > P$. In particular, we define:

$$P = a_1$$
$$Q = Q_0 - \gamma a_1 + \delta a_2.$$

with $\gamma, \delta \geq 0$.[20] In this sense, a_1 is a quantity focused action, while a_2 is a quality focused action. While this is a simplified model, a_1 can be thought of along the lines of fishing for extended periods to catch the maximum amount, traveling long distances to find fish in high volumes, or packing the hold tightly with fish. On the other hand, a_2 can be thought of as carrying extra ice on board to keep the catch cool, or taking care to ensure that the fish are not crushed. Q_0 is a baseline level of quality surplus.[21] Note also that a_1 enters negatively in Q, to capture the notion that actions taken to increase the quantity caught, such as packing the hold tightly with fish, often adversely affect quality.

We assume that neither P nor Q is contractible, but that P—the quantity surplus—is perfectly observable at the time of bargaining and Q—the quality surplus—is not. All parties know the value of Q_0, and because $P = a_1$ is observable, Q in effect has an observable portion: $\tilde{Q} = Q_0 - \gamma a_1 = Q - \delta a_2$.

Integrated suppliers

If a supplier is integrated, the firm has rights to the supplier's catch. However, because the firm cannot write contracts over Q and P, it cannot credibly commit to rewarding the supplier's actions. As a result, the supplier chooses $a_1 = 0$ and $a_2 = 0$, and the total surplus is simply Q_0.

Independent suppliers

Although neither Q nor P is contractible[22], the firm and supplier may bargain ex-post over the price of the delivery. We assume a Nash bargaining concept, with the supplier's bargaining coefficient equal to α. Because the supplier can always deliver its catch to the alternative quantity focused firm and receive P, the supplier must always receive at least P. The supplier additionally receives a share α of the observable portion of the surplus $\tilde{Q} - P$ that accrues to the firm: $\alpha(Q_0 - \gamma P - P)$. As a result, an independent supplier solves the problem:

$$\max_{a_1, a_2} \alpha Q_0 + (1 - \alpha\gamma - \alpha) a_1 - \frac{1}{2} a_1^2 - \frac{1}{2} a_2^2$$

This gives: $a_1 = (1 - \alpha\gamma - \alpha), a_2 = 0$, and social surplus is

$$Q_0 - \gamma(1 - \alpha\gamma - \alpha) - \frac{1}{2}(1 - \alpha\gamma - \alpha)^2 < Q_0$$

Because of the counterproductive actions to increase quantity $(a_1 > 0)$, and the adverse effects of those actions on the quality surplus, the surplus is lower when the suppliers are independent. As a result, the more efficient organizational structure to produce quality is vertical integration.

[20] More specifically, we assume that $0 \leq \delta \leq 1$ and $0 \leq \gamma \leq 1 - \alpha$. Also, note that P could itself be the result of a bargaining process between the boat and a quantity focused firm.

[21] This can be thought of as the amount that suppliers will catch before exerting any costly action, or perhaps more reasonably as the result of some limited contractual agreement that we abstract from.

[22] Alternatively, we could assume that only a portion of Q and P is non-contractible, and that we consider only this portion as in Baker *et al.* (2002).

It is worth noting that a number of assumptions made in this model are not strictly necessary to get this result. The relative efficiency of integration holds whether or not quantity focused actions directly negatively impacts the quality surplus (because of the inefficiency of quality actions), and would hold even more strongly if, for example, there were complementarities in the costs of quality and quantity actions.

3.3 Discussion

The theoretical role of vertical integration is a contentious topic. Our framing follows Baker *et al.* (2001, 2002) in combining elements of the incentives based theories in the tradition Holmstrom & Milgrom (1991) and the property rights theories in the vein of Grossman & Hart (1986). Such a framing is not the only type of model that would produce a relationship between integration and output quality. In actuality, integration is a complex organizational change whose causes and consequences operate through multiple mechanisms. However, because the foundations of the model above depend on a series of salient features of our context—unobservable quality, observable quantity, and alternative buyers that are less concerned with quality—and because we are able to directly test the predictions of the model, we see these alternative theories as complementary to the mechanisms our framework focuses on, rather than contradictory.

Our model presents a highly stylized, and somewhat stark, example to highlight a key intuition: that integration can act as a valuable tool for muting the incentives provided in the open market. We believe this starkness most simply portrays why firms in our context might want to integrate in order to produce high quality output. That said, this oversimplification does have a few drawbacks, most notably the lack of incentive to take quality focused actions, and to take any actions at all when integrated. This is in some sense a strong version of what are sometimes called the drone employees (Gibbons, 2005a) that appear in property rights theories of the firm that follow Grossman & Hart (1986). However, this feature may be easily remedied in more complex models that preserve the basic intuition and result. For example, assuming observability over Q induces quality focused actions among independent suppliers and—for sufficiently small values of δ—does not affect the main result. Perhaps more realistically, introducing dynamics into the model, with long-term relationships between firms and suppliers, creates an environment in which the incentives of the downstream and the upstream parties can be aligned through repeated interactions.

In Appendix C, we present and test the empirical implications of exactly such a dynamic model, in which we allow the downstream party to use relational contracts to incentivize the quality action. We posit that Q—the quality surplus—can be observed to the downstream party but only with some lag (e.g. once the inputs are processed and output quality is measurable). The firm can then offer the supplier a (delayed) reward contingent on this surplus, but can only credibly promise to pay this reward if it interacts repeatedly with the upstream party. In this context, we show that the value of the relationship can incentivize the supplier to take the first best actions, but that this sort of relational contract may be difficult to sustain if the supplier is independent. The intuition for this result is similar to our static baseline: independent suppliers own the rights over the inputs, and when the value of these inputs in their alternative use is high, they face incentives to renege on the relational contract and sell the goods in their alternative use.

Our model above also implicitly demonstrates the *costs* of integration. The market provides strong incentives for quantity, and for a low quality firm that is aiming to produce quantity, integration would only interfere with and lessen the strength of these incentives. Accordingly, quantity focused firms prefer independent suppliers. A similarly formulated model, with the roles of high and low quality firms switched (e.g. $P >> Q$), provides precisely this result.

In our stylized model, firms are either quality-oriented or not. In reality, a firm's output objectives are likely a combination of quality surplus and quantity surplus in which the weight attached to each depends on the demand the firm faces at a particular point in time. In this case, firms should not source all inputs from either integrated or non-integrated suppliers, but choose an intermediate organizational structure—that is, an intermediate level of integration—that depends on the relative importance of Q and P in the firm's *current* objective function.

The framework presented in this section motivates three empirical predictions that we test in the remainder of the paper:

1. Firms' organizational structure responds to variation in the *relative* profitability of producing high quality output. An increase in the quality premium—for example due to increased demand for high quality grades—leads to more integration, that is, a higher share of inputs from sourced from integrated suppliers.

2. The reason is that the actions of a supplier differ when the supplier is integrated. In particular, suppliers that get integrated *reduce* their effort to produce quantity, especially in ways that benefit quality.

3. As a result, the degree to which a firm or plant uses integrated suppliers affects output quality. Firms that use inputs from integrated suppliers produce higher quality output.

4 Data, Variables, and the Relationship of Interest

4.1 Data

The primary datasets we use to test our three predictions are the following:

Plant production. Administrative data on all plants' production come from Peru's Ministry of Production, which regulates the fishmeal industry. Every month plants are required to submit information on how much prime (high quality) and fair average (low quality) fishmeal they produce. Quality grade is thus directly reported in the plant production data, and subject to auditing by government inspectors. As discussed in Sub-section 2.2, the distinction between prime and fair average quality is based on the fishmeal's protein content. From these records, we construct each individual plant's and each firm's "high quality share of production" in a given month or production season.

Plant registry. We link the production data with an administrative plant registry that contains monthly information on each plant's (i) technological production capacity and (ii) owner, typically a multi-plant fishmeal firm.[23] We also use this registry to link the production data to export data. We can do so for almost all firms, but not the smallest firms, which use intermediaries to export.

Export transactions. Detailed data on the universe of fishmeal exports at the transaction level come from Peru's customs authority. We observe the date of the transaction, the export port, the destination country, the weight of the fishmeal, the value of the transaction, and the exporting firm.

[23] The data contains information on the number of metric tons that can be produced per hour with currently installed Low and High technology. 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).

Internal data from a large firm. One of the largest fishmeal firms in Peru shared its internal sales records with us. The firm owns many plants along the coast. The sales records include information on the shipment's 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 specific plant that produced a given shipment of fishmeal is reported.

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.[24]

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. Some observations are missing in the GPS dataset (and therefore also in our measures of boat behavior), but the patterns of missingness appear arbitrary. 95 percent of all boats and 99 percent of steel boats (which can be vertically integrated) that appear in the transactions data also appear in the GPS data.[25]

We merge many datasets and use a wide range of right-hand side and left-hand side variables across our empirical analysis. For this reason, the number of individual firms, plants, suppliers, and time periods available for each regression varies considerably. In the notes to our regression tables, we include information on the number of distinct i's and t's and, where relevant, an explanation of why some cannot be used in the relevant analysis.

4.2 Variables of interest

Our primary measure of an individual plant's output quality is the share of the fishmeal the plant produces in a given month that is of "prime" quality grades—a direct measure of quality whose interpretation requires no assumptions. We aggregate this measure up to firm or firm $\times$ season level to construct a corresponding measure of a firm's "high quality share of production".

We also construct a granular measure of the average quality grade—protein content—of the fishmeal a firm produces. While we do not directly observe the exact protein content of each export shipment, we can go beyond simply using unit prices and approximate the precise quality grade. This is because we observe quality grade-specific fishmeal prices in detailed (week$\times$export port$\times$protein content level) data recorded by a fishmeal consulting company. We infer the protein content of each of a firm's export shipments by comparing the corresponding unit values to this price data. To construct a firm$\times$season level measure, we average protein content across export shipments, weighting by quantity.[26] A priori, we have little reason to

[24] Information on engine power is only available for 2004-2006. However, changes in engine power are extremely rare in that period, so we treat this characteristic as fixed over time.

[25] The missingness seems to be driven by the regulator's data storage and maintenance and/or faulty equipment. In particular, there is no GPS data after June 2015, and before then, some boat-owners disappear from the data for a complete calendar year. Such missingness in the GPS data is unlikely to drive our results since we focus on within-boat changes in behavior upon integration/de-integration.

[26] The export transaction records do not report the specific plant that made the fishmeal so the inferred quality grade is only available at the firm level—except for data covering the fishmeal firm that shared internal data with us, including information on the plant

believe that this inferred protein content measure should be systematically biased.[27] Empirically, it is highly correlated with the "high quality share of production" directly observed for a firm's plants in production data, and with the exact quality grade reported in the sales records of a firm that shared its data with us. Nonetheless, we focus primarily on our directly observed measure of "high quality share of production."

To quantify vertical integration, we consider both the *number of suppliers a firm owns*, and the corresponding *share of inputs used in its production process* that come from integrated suppliers ("Share VI"). Share VI is our preferred measure of integration for a number of reasons. First, because we observe all transactions between *plants* and suppliers, we can construct Share VI in a consistent manner for both firms and individual plants. This allows us to move from the across-firm comparisons we make in Section 5 to the within-firm comparisons we make in Section 7. Second, we view Share VI as the more relevant measure when asking whether organizational structure and output quality are causally related: if firms vertically integrate when the quality premium rises because doing so allows them to increase input quality, then it should matter not just if a firm owns suppliers, but the degree to which the firm as a whole and its individual plants actually *source inputs* from those suppliers at the time of production. Third, and finally, Share VI automatically captures suppliers' size, allowing us to avoid assumptions on "scale effects"—e.g. how the benefit of one big integrated supplier compares to two small ones.

We also show the margins of adjustment driving changes in a firm's Share VI. In addition to the decomposition shown in Panel B of Table 2, we show in Section 5 and Appendix B that firms' Share VI response to variation in the quality premium is in large part driven by the extensive margin—acquiring and using new suppliers.

4.3 Relationship of interest

In Section 5 we begin our analysis of how exogenous changes in incentives to quality upgrade affect integration decisions. Before doing so, we first demonstrate that the basic relationship predicted by our model holds empirically: integration and output quality are positively correlated. To do so, 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} and VI_{it} respectively measure the quality of the output produced by firm i in season t and how vertically integrated the firm's organizational structure is in the same season. We control for the

that produced a given export shipment. One potential concern is that fishmeal can be stored for a short period, and hence firms could attempt to strategically time their export transactions. In practice the product is almost always sold before the next production season starts. (The reason why inventories are small—between +10 and -10 percent of total season production (see Appendix Figure A2)—is likely that many contracts are entered into 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 shipment can thus be traced back to a specific production season (but not a specific production month; constructing the inferred protein content measure at month level would require an assumption about how firms manage their inventories—for example, first-in-first-out versus first-in-last-out). 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. We thus exclude data from any firm×season observations that correspond to a firm's last season producing and exporting fishmeal, but the results are robust to including these observations. These issues are not relevant for our directly observed "high quality share of production" measure of output quality.

[27] Fishmeal is a vertically differentiated but otherwise homogenous product, and price differentials across shipments of a given quality level (and across firms producing a given quality level) in a given time period are negligible (see Sub-section 2.2). This implies that pricing-to-market, bulk discounts, etc, are not a concern.

technology the firm uses to convert fish into fishmeal,[28] HighTech_{it}, and firm and season fixed effects γ_i and δ_t. We thus estimate *changes* in output quality for those firms that vertically integrate in a given season, relative to other firms that do not. We cluster the standard errors at the firm level.

The results in Panel A of Table 3 point towards a meaningful baseline relationship between owning suppliers and output quality. The estimate in Column 1 implies, for example, that moving from the 25th to 75th percentile of number of boats owned is associated with an increase in high quality share of production of around 17 percent, although this estimate is not statistically significant. The estimate for our secondary measure of output quality, shown in Column 3, implies that moving from the 25th to 75th percentile of number of boats owned is associated with an increase in protein content of just under 10 percent of the range observed in Peru. This estimate is significant at the 1 percent level.[29]

In Panel B we show that, beyond simply owning suppliers, what matters for output quality is Share VI: *the share of a firm's supplies coming from integrated suppliers at the time of production*. The results imply that a firm that uses inputs coming entirely from integrated suppliers rather than inputs entirely from independent suppliers sees a share of high quality output that is roughly 38-41 percent (28-31 percentage points) higher, and an average protein content that is higher by roughly 23 percent of the range observed in Peru.

As shown in Appendix Table A2, the characteristics of integrated suppliers unsurprisingly differ from the characteristics of independent suppliers: integrated suppliers are on average bigger and have more advanced equipment than independent suppliers, while the average switcher falls in between the average always-independent boat and the average always-integrated boat, but closer to the latter. However, in Panel C we show that the results in Panel B are not not driven by observable, time-varying supplier or firm characteristics. We control for a series of supplier characteristics, as well as the firm's share of total industry production and the size of its production. Doing so has little impact on the estimated coefficient.[30]

In Appendix C, we consider whether the relationship between output quality and integration might be the result of long-term supplier-firm relationships, rather than ownership per se. This does not appear to be the case, as we do not observe the association between quality and the share of inputs coming from suppliers in long-term relationships that we do for Share VI. In other words, it is integration itself, not the relationship, that co-varies with output quality. This is in line with the predictions of a dynamic version of our model, also shown in Appendix C.

The relationship between a firm's organizational structure and its output quality that we established in this sub-section is the starting point of our empirical analysis. This basic relationship is consistent with this paper's hypothesis. However, it is also consistent with the alternative theories discussed in the introduction. In these theories, a correlation between integration and output quality arises, but the relationship is either not causal or not known to (or ignored by) firms. We show evidence that is hard to reconcile with such

[28] A firm's production technology is an important potential determinant of output quality, and one that could plausibly correlate with organizational structure (Acemoglu *et al.* , 2007, 2010). We thus control for installed HighTech_{it}, i.e., steam drying (High) technology. At the firm level, HighTech_{it} is equal to the share of installed capacity that is of the high type.

[29] Firms in the 25th percentile own four boats, while firms in the 75th percentile own 36 boats, and the range of protein content observed in Peru is approximately 63-68 percent. The Ministry of Production has not responded to our inquiries about the exact percentage cut-off they use to define prime (high quality) fishmeal (but our estimates do not make use of such a cut-off).

[30] Controlling for the share of inputs coming from steel boats, high capacity boats, and boats with a cooling system leaves the magnitude and significance of the coefficient on share of inputs coming from VI suppliers essentially unchanged. 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. Controlling for the firm's share of total industry production and Log(production) also leaves the magnitude and significance of the coefficient on Share VI essentially unchanged.

explanations in the next section.

5 The Quality Premium and Organizational Structure

We now show that the relationship between output quality and vertical integration we established in the previous section reflects an explicit organizational choice firms make *in order to* "climb" the quality ladder. Specifically, Peruvian fishmeal manufacturers integrate suppliers when the returns they earn from upgrading quality rises for exogenous reasons. This finding provides empirical support for the prediction that a vertically integrated organizational structure is efficient for producing high quality output. We provide additional evidence that underscores the difficulty of reconciling this finding with alternative theories.

5.1 Estimating how the quality price premium affects vertical integration

We begin by showing that firms as a whole *do* vertically integrate when the quality premium is high. We quantify Integration_{it}—a firm's decision to integrate (de-integrate)—as a season-to-season increase (decrease) in the share of inputs the firm obtains from integrated suppliers (and show estimates for the level corresponding to this difference in the Appendix, with qualitatively similar but less precisely estimated results).[31] We measure the quality premium as the difference between the (log) price of high and low quality fishmeal.

We first show results from simple descriptive regressions of the form:

$$\text{Integration}_{it} = \alpha + \beta \text{QualityPremium}_t + \eta_i + \varepsilon_{it}. \tag{2}$$

Here, $\beta > 0$ indicates that firms vertically integrate when the quality premium is high, and η_i represents a firm fixed effect.

The first column of Table 4 shows the results from this specification, omitting firm fixed effects. There is a positive baseline correlation between the quality premium and firm integration. The second column replaces QualityPremium_t with two dummy variables: an indicator equal to one when the quality premium is above the mean, and an indicator equal to one when the quality premium is below the mean (as these are exhaustive categories, the constant is suppressed). We see a positive and significant coefficient on the high quality premium indicator, suggesting that firms vertically integrate when the quality premium is high. We also see a negative coefficient on the low quality premium indicator, consistent with firms *de-integrating* when the quality premium is low, although the estimate is smaller and not statistically significant. The third column repeats the specification from equation (2), now including firm fixed effects. The estimated coefficient is extremely similar to that in column 1. In sum a relationship between the quality premium and vertical integration is thus evident in the time series.

In Column 4 we show that firms' response to the quality premium is not due to associated income shocks or general incentives to expand or reduce production. We repeat the regression from Column 1, but with the Log(Average Price)—the (equal-weighted) average price of high and low quality fishmeal in season t—replacing the quality premium as the regressor of interest. The estimated coefficient is near zero and

[31] Specifically, if VI_{it} is defined as Share VI, we analyze $\text{VI}_{it} - \text{VI}_{it-1}$, where t indicates a season. In columns 3-10 of Appendix Table A3, we show all of our results using VI_{it}, rather than the difference. Furthermore, in Appendix Table A4, we show that our results are robust to a logit transformation of VI_{it} and VI_{it-1}, i.e. $\text{Log}(\frac{\text{VI}_{it}}{1-\text{VI}_{it}})$.

insignificant, indicating that firms are not more likely to vertically integrate when the overall price level is high. Figure 2 shows that the quality premium is only weakly correlated with average prices in Peru. It is thus not surprising that firms respond differently to the two.

5.2 Differential responses by firms with more versus less capacity to upgrade

We next consider how the quality premium differentially impacts firms' integration decisions depending on their *capacity* to upgrade quality. Firms that are already producing exclusively high quality output have no scope to upgrade the average quality they produce. For these firms, an increase in the quality premium cannot induce an increase in the high quality output share and therefore should not lead to a change in organizational structure. Conversely, a firm that produces some mix of high and low quality output has capacity to raise quality. If vertical integration indeed enhances output quality, we expect to see these firms integrate when the quality premium rises.

To investigate this differential response, we interact QualityPremium_t with measures of a firm's capacity to upgrade in season t. Our primary measure is a firm's *Upgradable Share of Production*, that is, the share of low quality in its season $t-1$ production. For example, a firm currently producing 25 percent high quality output has a 75 percent *Upgradable Share of Production*. As a secondary measure, we also consider a binary indicator, *Low Quality Producer*, which is equal to one for firms that produced at least some low quality output in season $t-1$. We run specifications of the form:

$$\begin{aligned}\text{Integration}_{it} = \alpha &+ \beta(\text{UpgradingCapacity}_{it-1} \times \text{QualityPremium}_t) \\ &+ \gamma\text{UpgradingCapacity}_{it-1} + \eta_i + \delta_t + \varepsilon_{it}.\end{aligned} \tag{3}$$

where $\text{UpgradingCapacity}_{it-1}$ refers to either *Upgradable Share of Production* or *Low Quality Producer*. This regression is a generalized difference-in-differences in which firms that are more versus less exposed to changes in quality upgrading incentives are compared in each production season, and in each of these seasons the quality premium may be relatively high or relatively low. We control for $\text{UpgradingCapacity}_{it-1}$ itself, firm and production season fixed effects (γ_i and δ_t), and cluster the standard errors at the firm level.

Before showing the results from estimating (3), we briefly discuss the variation we exploit. The season-to-season variation in the quality premium is shown in Figure 2. While the long-term trend is weakly positive during our data period, the quality premium fluctuates substantially from season to season, sometimes rising and other times falling. Additionally, firms' upgrading capacity evolves over time.[32] For example, 19 of the 37 firms in our sample are characterized as both a *Low Quality Producer* and a not-*Low Quality Producer* at some point in our sample. Of the remainder, about half are always *Low Quality Producers* and about half never *Low Quality Producers*. Overall, 42 percent of all firm-season observations in our data are classified as *Low Quality*. A strength of our approach is thus that the high and low Upgrading Capacity_{it-1} firms being compared across seasons vary. Furthermore, the set of low quality producers is not limited to a small number of, or to small, firms.[33]

[32] The fact that we control for the characteristic that defines a firm's exposure to a "treatment" variable that varies across time—here $\text{UpgradingCapacity}_{it-1}$—distinguishes our approach from traditional Bartik instrument approaches (see e.g. Goldsmith-Pinkham *et al.* , 2019).

[33] The mean number of plants active in firm-season observations that are classified as *Low Quality* is 2.8, versus 3.7 for not-*Low Quality* firm-seasons). The 25th and 75th percentiles of number of plants are 1 and 4 for *Low Quality* producers, versus 1 and 6 for not-*Low Quality* firm-seasons.

Columns 5 of Table 4 show OLS results from estimating (3) when using our primary measure of $\text{UpgradingCapacity}_{it-1}$, which is *Upgradable Share of Production*. We find that firms with greater scope to shift from low to high quality production are more likely to vertically integrate when the quality premium is high—consistent with our hypothesis and the model in Section 3. The same is true in Column 6, where we define $\text{UpgradingCapacity}_{it-1}$ as *Low Quality Producer*, our secondary measure. It is worth noting that if—not implausibly—firms producing a high share of high quality output face a lower marginal cost of either quality upgrading or vertical integration, then such a countervailing force would if anything *strengthen* the support for our hypothesis implied by the results in columns 5 and 6 of Table 4.[34]

A potential concern is that some omitted factor might influence both Peruvian firms' incentive to integrate and the quality premium (or, alternatively, that the quality premium is itself influenced by integration decisions). To address this concern, we develop an instrumental variable strategy based on the *regulatory fishing quotas* of other top fishmeal producing countries. These aggregate fishing quotas, which directly constrain each country's fishmeal production, are ideal instruments because they are set based on sustainability considerations. Other countries' fishing quotas are thus unlikely to correlate with factors influencing Peruvian firms' integration decisions, except via their influence on market prices. Furthermore, because the other top exporters all specialize in producing either high or low quality fishmeal, shifts in these quotas are likely to impact the *relative* prices of high and low quality fishmeal, and hence the quality premium. While they may also affect the average price level, we know from Column 4 of Table 4 that such shifts are unlikely to impact integration decisions.

Specifically, our instruments are the seasonal quotas for the type of fish used to produce fishmeal in each of the top-five fishmeal exporting countries for which quota information could be found, excluding Peru: Chile, Denmark, and Iceland, all of which specialize in high quality grades.[35] We interact these quotas with $\text{Upgrading Capacity}_{it-1}$ to instrument for $\text{Upgrading Capacity}_{it-1} \times \text{Quality Premium}_t$ as follows:

$$\begin{aligned}\text{Upgrading Capacity}_{it-1} \times \text{QualityPremium}_t = \alpha + \sum_c \beta_c\, \text{UpgradingCapacity}_{it-1} \times \text{FishingQuota}_{ct} \\ + \beta_2 \text{UpgradableShareOfProduction}_{it-1} + \gamma_i + \delta_t + \varepsilon_{it}\end{aligned} \tag{4}$$

where c is an exporter country, and FishingQuota_{ct} is the log fishing quota of country c in season t.

The first stage, shown in columns 7 and 8 of Panel B of Table 4, is strong. The estimated coefficient on all three countries' quota is significant and negative, reflecting our proposed mechanism: because increases in the quotas of these high-quality producing countries raise the global supply of high quality fishmeal, this decreases the quality premium.

The second stage with $\text{Upgrading Capacity}_{it-1}$ defined as *Upgradable Share of Production* is shown in Column 7 of Table 4. The IV estimate of $\hat{\beta}$ is of very similar magnitude to the OLS estimate in Column 5

[34] Suppose firms producing a higher share of high quality output, in addition to their mechanically lower *scope* for further quality upgrading, also face a lower marginal cost of quality upgrading. This would only be a concern for our strategy of this lower cost of upgrading was also related to those firms' ease of integration. (Similarly, a potential lower marginal cost of integration for firms producing a higher share of high quality output would only be a concern if the lower cost of integration was also related to those firms' ease of upgrading). The logic of our approach—the argument that firms with high *scope* for quality upgrading face stronger incentives to upgrade quality when the quality premium is high—would then need to not only hold, but to outweigh any such countervailing forces for this empirical strategy to yield evidence supporting our hypothesis.

[35] Chile, Denmark and Iceland have had aggregate fishing quotas in place for the relevant fish species throughout our sample period (IFFO, 2014; Tanoue, 2015; IRF, 2017; European Commission, 2018). Thailand—the fifth of the top-five fishmeal exporting countries, which specializes in low quality grades—appears to have introduced such a system in 2015, but quota information for Thailand could not be found.

and highly significant. The estimate in Column 7 implies that, when the quality premium in Peru rises by 5 percent, a firm with a high upgradeable share of production—one that produces only low quality output—increases its Share VI by about 30 percent when compared to a firm producing only high quality output. The IV estimate with Upgrading Capacity$_{it-1}$ defined as *Low Quality Producer* is shown in Column 8; this estimate is similar in magnitude to the corresponding OLS estimate in Column 6 but slightly lower and not statistically significant.

In Sub-section 2.3 we decomposed the overall variation in Share VI into the components explained by each of the three margins through which firms can integrate their production process. In Appendix Table B2 we replace Share VI itself with these three margins in IV regressions like the one in Column 7 of Table 4 and the corresponding OLS regressions, which are analogous to Column 5. The results show that firms' Share VI response to changes in firm-specific incentives to upgrade quality arising from exogenous variation in the quality premium is almost entirely driven by the extensive margin, that is, acquiring and selling suppliers. The intensive margin response—the intensity with which firms use their integrated suppliers—is also positive and significant, but of much smaller magnitude. Use of independent suppliers appears not to drive manufacturers' Share VI response to the quality premium: we find a small and negative but statistically insignificant coefficient with this margin on the right-hand side.

5.3 Robustness

Our instrumental variables strategy rests on the assumption that the quantities produced by other top fishmeal exporting countries affect integration decisions in Peru through their impact on market prices. If this argument is correct, we would expect these production volumes to manifest themselves in the price of high quality fishmeal *locally*, which in turn should impact the quality premium in Peru. In columns 9 and 10 of Table 4, we repeat the regression in equation (4), but now instrument using the *high quality-grade specific price* in other top exporting countries, rather than the fishing quotas themselves. High quality fishmeal prices in Chile, Denmark, and Iceland—shown in Appendix Figure A4, along with Peru's price—are highly correlated with those in Peru.

For both definitions of *Upgrading Capacity*, the second stage results closely match the OLS results in terms of magnitude and statistical significance. Of course, the price of high quality output in, say, Chile may be responding to the price in Peru. Still, it is reassuring for our fishing quota-based IV strategy that variation in the quality premium that correlates with the prices in other top fishmeal producing countries is associated with integration in Peru. The signs in the first stage are slightly more mixed: positive for the prices in two—but not all three—of the other top exporters. However, it is not clear that the residual variation in the equilibrium price in Denmark, conditional on the price in Chile, will necessarily be predictive of the price in Peru. In Appendix Table A5 we run pairwise versions of our first stage regression. Indeed, when each country is included individually, we see the expected positive and significant correlation between the price in each country exporting large amounts of high quality fishmeal and the quality premium in Peru (interacted with our measure of *Upgrading Capacity*).

In the first two columns of Appendix Table A3, we show two further robustness exercises for our primary, fishing quota-based IV specification.[36] To rule out the possibility that the estimated integration response to the quality premium is driven by changes in Peruvian firms' scale resulting from changes in other

[36] For brevity, we consider only our primary measure of Upgrading Capacity, *Upgradable Share of Production*, throughout this table.

countries' fishing quotas, we control in Column 1 for changes in total firm production. Specifically, we include $\log(\text{production})_t - \log(\text{production})_{t-1}$ as a control. The magnitude and significance of the estimated coefficient is effectively unchanged relative to Column 7 of Table 4.

In the second column of Appendix Table A3, we show that our approach is not confounded by the instrument's reliance on exporters that specialize in high quality grades. In this specification, we include Thailand—the fifth of the top-five fishmeal exporters, which specializes in low quality fishmeal—in the first stage. While information on Thailand's fishing quotas was not available, we use its *realized* production level. Again, the sign and significance of our second stage estimate is effectively unchanged. Perhaps more notable is the first stage: the negative signs on the quotas of all three of the high quality producing countries remain, but we see a positive and significant sign on the quantity exported by Thailand. This is consistent with the intuition underlying our instrument, that is, an increase in the quantity produced by a low quality exporter causing the low quality price to drop, increasing the quality premium.

In Appendix D we exploit a different form of variation and find results consistent with those discussed in this sub-section. We show that manufacturers respond the same way to variation in firm-specific, quality-differentiated demand shocks as they do to analogous shocks to the quality price premium—integrating suppliers and increasing Share VI when relative demand for high quality grades increases, and selling boats and decreasing Share VI when relative demand for high quality grades decreases. To do so we construct instruments for firm-specific demand shocks that exploit the fact that each importer country tends to import very specific quality grades; that importer countries' relative demand fluctuates over time; and that changes in demand from a given country matter more for firms that previously exported to that country. We follow many fruitful applications of such an approach in the trade literature (see e.g. Park *et al.* , 2010; Brambilla *et al.* , 2012; Tintelnot *et al.* , 2017); our implementation closely follows Bastos *et al.* (2018).

5.4 Interpretation

The results discussed in this section are consistent with this paper's hypothesis and the theoretical framework in Section 3. In our model, a firm integrates suppliers when its returns to upgrading quality rise because it is difficult to ensure that independent suppliers deliver high quality inputs when the quantity they produce is valued by other buyers in the market. We now consider whether firms' decision to integrate suppliers when the benefits of quality upgrading rise can be explained by alternative theories.

A first possibility is that firms simultaneously choose their organizational structure and output quality, and shocks—for example to demand (Legros & Newman, 2013; Alfaro *et al.* , 2016)—affect both without the two being directly related. Such a story is difficult to reconcile with the fact that Peruvian fishmeal manufacturers integrate suppliers in response to increases in the *relative* price of high quality output, but not in response to increases in the average price of fishmeal.

The same is true for a second possibility, namely that firms, when the benefits of producing high quality output rise, buy suppliers so as to restrict competitors' access to independent suppliers and thereby capture a higher share of a newly appealing market segment that happens to be the high quality one (Ordover *et al.* , 1990). If such a story explained our results, controlling for the size of a firm's production should reduce the estimated coefficient on the quality premium, and we should see manufacturers integrating suppliers also when the price of low (or any) quality fishmeal rises—unless integrated suppliers are more useful when producing high quality output (as we conjecture).

A third—and related—possibility is that the integration decisions we observe are driven by supply assurance motives (Macchiavello & Miquel-Florensa, 2016; Martinez-Carrasco, 2017). One potential argument along these lines is that an increase in the quality premium directly allows firms to satisfy a latent demand for supply assurance, e.g. by releasing a credit constraint. However, such a story is inconsistent with the facts that (i) those producing primarily low quality—and hence benefiting the least from the quality premium cashflow-wise—are the most likely to integrate when the quality premium rises, and (ii) we see no integration response when the average price rises. An alternative supply assurance story is that an increase in the quality premium causes firms to match with new foreign buyers of fishmeal who demand both high quality and supply assurance simultaneously. This, and other supply assurance-based stories, assumes that an increase in our primary measure of vertical integration—Share VI—allows firms to better assure supply in the context we study. While we cannot rule out a role for supply assurance in the integration decisions of Peruvian fishmeal producers, we find little empirical evidence that use of integrated suppliers improves their access to supply in our data.[37] Note, however, that a firm objective of integrating to secure access to suppliers who are incentivized to deliver the high quality inputs that are needed to meet the demand for high quality output—exactly the interpretation we favor—could also be labeled supply assurance. We conclude that manufacturers vertically integrate when the quality premium rises for exogenous reasons at least in part *in order to* produce a higher share of high quality output.

6 Firms' Organizational Structure and Supplier Behavior

The model in Section 3 predicts that integration is an efficient organizational structure for producing high quality output for a specific reason: because integration weakens suppliers' incentives to maximize quantity in ways that might be detrimental to the quality of the inputs they produce. As a result, we expect to see suppliers reduce behavior that increases quantity but is harmful to quality when integrated.

6.1 Estimating how vertical integration affects suppliers' quality-enhancing actions

We analyze three measures of behavior that capture the tradeoff between input quantity and quality in trip level data: the total quantity supplied, the maximum distance travelled from the delivery port, and the total time the supplier spends at sea on a given trip. (In addition to these, we also show results for the total number of trips per season). The first of these three we observe in supply transactions data, while the second two are constructed from boat GPS data. The total quantity supplied is a direct measure of actions taken by the supplier to increase quantity. However, this variable also relates to input *quality*. This is because the supplier may need to forego quality-increasing actions—such as bringing a lot of ice on board to keep it fresh, not stacking fish high on top of each other to prevent smashing it, etc—in order to bring back a high quantity of fish. The maximum distance travelled and total time spent at sea are chosen because they explicitly capture quality-decreasing actions that will tend to increase quantity. Fish freshness—which depends on the time between catch and delivery—is paramount for the protein content of fishmeal. As the

[37] First, integration if anything appears to be associated with greater volatility of daily supply in our data. This can be seen from running firm×season level regressions like those in Table 3 and equivalent plant×month level versions show in Table 6 with the standard deviation of supply across days replacing output quality on the left-hand side. Second, constructing an approximation to the test used in Macchiavello & Morjaria (2015) in our setting reveals little evidence that integrated suppliers are more reliable when positive demand or negative supply shocks occur. These results are available from the authors upon request.

Food and Agriculture Organization of the United Nations puts it, "Freshness of raw material is important in its effect on the quality of the protein in the end product [fishmeal]. The importance of minimizing the time between catching fish and processing, and of keeping the fish at low temperatures by icing [which reduces the amount of fish a boat can fit], has already been mentioned" (FAO, 1986, sub-section 10.1.2). Captains must thus balance traveling further and longer to catch more fish against ensuring freshness. Because all three of these measures of behavior increase quantity but decrease quality, we expect them to decrease post-integration (or increase post-separation).

Our empirical strategy focuses on "switchers". Switchers are suppliers that are either bought or sold by a fishmeal firm during our data period and observed supplying the same plant within the firm in question both before and after the change in status. We include supplier×plant fixed effects and hence compare the behavior of a *specific* supplier within a *specific* relationship before versus after integration (or de-integration).

As discussed in Section 2, we observe 103 instances in which a fishmeal firm acquires a supplier that is initially owned independently; 32 instances where a supplier is sold from a fishmeal firm to an independent buyer; and 50 instances where a supplier is sold from one fishmeal firm to another. Conveniently, a subset of our qualifying switches—in which the supplier is observed supplying the firm in question both before and after the change in status—comes from this last set of firm-to-firm supplier transitions. This is because integrated suppliers sometimes supply other fishmeal firms.[38] We exploit these transitions in which an always-integrated supplier's relationship with a specific firm changes below.

We do not observe any significant *changes* in suppliers' characteristics when switching in or out of integration with the plant supplied. Thus, while any average differences between the behavior of independent and integrated suppliers might be attributable in part to boat characteristics[39], our analysis of *within* supplier changes in behavior is unlikely to be influenced by these attributes. Recall also that we saw in Figure 1 that suppliers that get integrated or sold deliver to the acquiring/selling firm 63 percent of the time *before integration* (or after de-integration): integration typically implies a simple change in the formal status of the relationship between a firm/plant and a supplier engaged in frequent and continuing interactions.

We estimate regressions of the following form:

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

where B_{ijt} is a measure of the behavior of supplier i, delivering to plant j, on date t. $[\text{VI} \times \text{supplies owner firm}]_{ijt}$ 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 effects and Supplier×Plant fixed effects (γ_{ij}) to focus on how integration affects the behavior of a specific supplier supplying a specific plant. We cluster the standard errors at the boat level. We present our results in Table 5, and show both the total number of observations and the total number of unique suppliers included in each column.

Column 1 of Panel A of Table 5 shows that, when integrated and supplying a parent plant, a boat delivers on average about ten percent less per trip compared to when it supplies the same plant while independent. This result is clearly consistent with integration offering lower-powered incentives to produce quantity,

[38] A firm's output objectives may vary across time within seasons, and fish move around and the location of a catch constrains the set of plants a boat can deliver to. As a result, and as seen in Figure 1, Panel (a), integrated suppliers on average deliver to other firms just over 10 percent of the time.

[39] As noted in Sub-section 4.2 and shown in Appendix Table A2, on observable features, the average switcher falls in between the average always-independent boat and the average always-integrated boat, but closer to the latter.

and also suggests that integrated suppliers dedicate more of their storage capacity to ice and/or are more concerned with crushing fish. Columns 2 and 3 show that boats fish approximately five percent closer to the port of delivery, and spend on average three percent less time at sea on a trip when integrated with the plant supplied.

In Panel C of Table 5 we consider an element of boat behavior that is aggregated to the season level. In particular, we regress the log total number of trips per season on season and supplier fixed effects, as well as an indicator equal to one if the supplier is vertically integrated in season t. While our results in Panel A show that suppliers deliver a lower quantity per trip once integrated, this does not appear to translate into less overall effort at the season level. In fact, our results indicate that a given supplier conducts significantly more trips each season when integrated. In other words, integration is associated with more frequent trips that are shorter, closer, and result in lower quantities.

These results suggest that, when integrated, suppliers reduce costly actions associated with long trips, and bring back fresher fish as a result—as the managers in the industry we interviewed reported to us. (In the words of a prominent executive of Peru's National Fisheries Society: "Independent boats prefer to extend their fishing trips [until] they are at full hold capacity, so as to maximize quantity, and this is not good for fish quality...as a consequence of integration, they must adopt my rules. Things like saying, 'hey, you must offload raw 24 hours after having caught it, at the maximum."' (Authors' translation).)

A potential concern is the possibility that these results reflect a correlation between the timing of boat purchases and trends in behavior. For example, a firm might choose to purchase a supplier *because* that supplier has recently begun prioritizing quality. To address this, Appendix Figure A5 plots the trends in each of the three trip level behaviors we study in the period just before and after integration as measured with the raw data. Specifically, for the set of Supplier$\times$Plant pairs that transition from non-integrated to integrated, we consider interactions in the 45 days (Panel A) or 45 trips (Panel B) before and after integration. These plots show no evidence that quantity-oriented boat behaviors trend downward prior to integration. Furthermore, all three behaviors display an evident drop just after integration.

In our model, integration is defined by asset ownership, as in Grossman & Hart (1986). Indeed, suppliers' change in behavior appears to be the result of integration itself, as opposed to any long term relationship that coincides with integration. In Appendix Table C1, we show that—absent integration—repeated interactions with the same plant do not lead to a change in quality-increasing actions, consistent with the predictions of the dynamic version of our theoretical framework also shown in Appendix C. Thus, while repeated interactions help fishmeal manufacturers and independent suppliers exchange supply and demand assurance (Martinez-Carrasco, 2017), they appear not to offer an alternative way to achieve the change in quality-conducive incentives associated with integration in the context we study.

6.2 Interpretation

In this section we have seen that a given supplier supplying a given plant takes more quality-oriented and less quantity-oriented actions when the two are vertically integrated. Our interpretation is that integration dampens high-powered incentives to prioritize quantity over quality that suppliers face on the open market. Other changes in incentives that arise due to integration could also play a role. Perhaps the most plausible possibility is that what constrains suppliers' input quality is not their incentive to prioritize quality but their knowledge of how to do so. If so, firms may be reluctant to "teach" a supplier how to upgrade input quality if the supplier is independent (Pigou, 1912). We can shed some light on the likelihood that such a story explains our results in this section by exploiting the fact that integrated suppliers occasionally deliver inputs to other firms. We analyze the behavior of suppliers that are *always* integrated with a fishmeal firm, but sold from one firm to another during our sample period, and that supply a plant belonging to the acquiring and/or the selling firm both before and after the sale. We thus continue to focus on changes in supplier behavior *within* a supplier×plant pair.[40]

As seen in Panel B of Table 5, we find quite similar—even slightly larger—effects compared to Panel A. If acquired, a supplier changes its behavior consistent with prioritizing quantity less—to the benefit of quality—while delivering to the acquiring firm. This pattern is identical to how previously independent "switchers" change their behavior once integrated, suggesting that a story in which integration enables knowledge transfer from Peruvian manufacturers to their suppliers is unlikely to be the primary explanation behind the difference in supplier behavior when integrated. In other contexts, such knowledge transfers may provide an additional—or the primary—motivation for vertical integration (see Atalay *et al.* , 2014).

The results in Panel B of Table 5 also underscore the patterns shown in Appendix Figure A5: that it is not the case that firms simply choose to integrate suppliers that have already begun changing their behaviors. This provides further support for the parallel trends assumption that underlies a causal interpretation of the results in Panel A.

Another alternative explanation of the change in supplier behavior when integrated is that our results simply reflect the fact that integrated suppliers face low-powered, fixed pay incentives, the behaviors we see not generating any input quality benefits that manufacturers are aware of and *act on*. Such a story is difficult to reconcile with the results in Panel B of Table 5—integrated suppliers behave "as independent suppliers" when supplying firms other than the parent firm. The intuition captured in the framework in Section 3 and the corresponding evidence in Section 5 suggest that it is likely in the parent firm's interest for its integrated suppliers to prioritize quantity over quality in such situations. A mechanism focusing on integrated suppliers' low-powered in isolation is also difficult to reconcile with this paper's central finding that firms integrate suppliers when the quality premium rises for exogenous reasons, but not when the general price level increases. Suppliers' pay system may affect their behavior, but the evidence discussed in this sub-section suggests that, if so, it does so differently when combined with incentives that come from delivering to a parent firm.

7 Vertical Integration and Output Quality

In Section 5 we saw that firms vertically integrate when the benefits of shifting from low to high quality production rise. In Section 6 we saw that suppliers that get integrated behave in a more input quality-increasing and less input quantity-increasing manner. In this section we show that plants' *output* quality responds to integration exactly how we would expect if the integration-induced change in supplier behavior improves input quality. That is, we show that plants with a greater share of vertically integrated inputs produce higher quality output. This provides empirical support for our model's third prediction, namely that vertical integration is an *effective* organizational strategy for producing high quality output. It is also consistent with the reports provided by the managers in the industry we interviewed. For example, Ricardo

[40] To implement this analysis we repeat the specification in Equation 5, but define I[VI×supplies owner firm] to be equal to one if the supplier is (i) always owned by a fishmeal firm, and (ii) currently delivering to its parent firm.

Bernales Parodi—Managing Director of Pesquera Diamante, Peru's third largest fishmeal company—said the following: "From the boat to the factory, and to the commercialization, the flour has quality A, B, C and D. If I only bought from my boats, I would make an effort so that 95 percent would be A and B, and only 5 percent of C and D. But when buying from third parties, I end up with 20 percent of C and D." (Authors' translation).

We first show that there is a robust relationship between changes over time in the share of inputs *individual plants* obtain from integrated suppliers (Share VI) and changes in their output quality that goes beyond the firm level evidence discussed in Sub-section 4.3. We then attempt to isolate shifts in a plants Share VI that occur for plausibly exogenous reasons. We show evidence from two IV approaches. The first exploits geographic variation in the local concentration of wooden boats—a particularly type of supplier that is prohibited from being integrated by regulation—as well as in independent (non-integrated) boats more broadly. The second exploits variation in weather patterns across the ports around which plants are clustered. Together, the results we present strongly suggest that the relationship between Share VI and output quality arises because integration increases output quality.

7.1 Estimating how vertical integration affects output quality

If integration increases output quality because integrated suppliers deliver higher quality inputs, then the relationship between Share VI and output quality we observe at the firm level should hold at the *plant* level as well. This is what we find in Table 6. We repeat regression (1) from Sub-section 4.3, but now at plant (i) $\times$ month (t) level, the lowest level at which we directly observe output quality.

The sample consists of all 94 plants we observe across Peru. We include plant and month fixed effects and thus focus on variation in Share VI across months within a given plant.[41] The results in columns 1 and 2 of Table 6 imply that the share of a plant's output that is of the high quality type would be 8-12 percent higher if its parent firm were to integrate all (relative to none) of the plant's suppliers. We also find the same integration-quality relationship across different plants *within the same firm* over time, as shown in Appendix Table A6. There we use internal data provided to us by a single major firm.[42]

In combination with Table 3, the first two columns of Table 6 establish a positive, statistically significant, and quantitatively consistent association between Share VI and directly observed output quality at both the firm and plant levels. Of course, the fact that these correlations hold for individual plants does not rule out non-causal interpretations. It could be that plant or port specific shocks—for example to productivity—occur and simultaneously impact both the quality of a plant's output and the share of the plant's supply coming from integrated suppliers. Alternatively, there might be particular plant-level strategic choices that lead plants to simultaneous increase Share VI and produce higher output quality without a causal link between the two. We now turn to two IV strategies that help us isolate plausibly exogenous variation in Share VI at the plant level.

[41] We observe whether each plant has any high technology installed so HighTech$_{it}$ is now a dummy variable.

[42] The firm's data reports which plant produced the fishmeal included in a given export shipment. In addition to "share high quality", for this firm's plants we can thus measure output quality also as the fine-grained quality grade inferred from exports unit values and auxiliary price data, as we do for firms in columns 3 and 4 of Panel B of Table 3. The magnitude and significance of the estimates are very similar to those in Panel B of Table 3.

7.2 Instrumenting with the presence of wooden and independent boats

Our first IV strategy exploits the local presence of wooden fishing boats—which are, by law, independently owned—as a source of variation in a plant's Share VI. These, and other independent boats, move up and down the coast as a function of weather, presence of fish, and other factors. The logic of our instrument is simply that, at times when there happens to be an abundance of independent suppliers in a given area for exogenous reasons, firms are more likely to use those suppliers. A plant's choice of suppliers is the result of a complex optimization process involving output quality objectives on the one hand and the relative cost of using integrated versus independent suppliers on the other. At times when input from independent suppliers is relatively cheap, optimizing plants will tend to decrease their Share VI—even holding their incentives to produce quality constant. When independent suppliers are scarce, the cost of their inputs is likely to be high, and vice versa. This suggests that measures of the presence of independent suppliers may serve as instruments for a plant's Share VI.[43]

With this in mind, we consider the number of wooden—and hence independent by law—suppliers active in a port (cluster of plants) in a given month as a proxy for the relative cost of using independent suppliers. For this to be a valid instrument, it must not impact or be correlated with output quality other than via Share VI. Of course, a plant's quality objectives may themselves influence suppliers' whereabouts. The plant may for example request deliveries from particular wooden suppliers. We thus use a *leave-firm-out* measure of the presence of independent-by-law suppliers in a given port *during a given period*. In particular, our instrument for Share VI is the number of wooden boats present, excluding any that supply the firm to which the plant in question belongs. We also show results for an analogous instrument using all independent suppliers, not restricting to wooden boats.

We believe the exclusion restriction to be valid given two key assumptions: (i) plants are effective price-takers in the local market (or, more specifically, that an individual plant's actions that correlate with quality production do not influence the likelihood that independent boats serve *other* firms in the port), and (ii) that the presence of independent boats is not correlated with port level shocks that influence the production of output quality at all plants in a port. Of course, it is possible that these assumptions do not hold. However, given our leave out strategy and a robustness exercise provided below that exploits the lagged presence of wooden and independent suppliers, we believe (i) to be quite plausible. Furthermore, two pieces of evidence indicate that (ii) is reasonable. Firstly, beyond the presence of wooden boats, we find no evidence of port-level correlations in the production of output quality.[44] That is, port-level shocks to output quality appear limited in general. Secondly, from our understanding of the industry, the types of factors that are attractive to independent fishing crews (who are paid per ton delivered)—e.g. an abundance of fish close to a port—are ones we expect to be positively correlated with quality production. This stands in contrast to the argument underlying our IV, which predicts a negative relationship between independent boats and quality production (and which we confirm below).

[43] It is important to note that the use of wooden suppliers is not limited to small firms. The proportion of inputs sourced from wooden boats is relatively stable—and if anything slightly increasing—across the distribution of firm size. Single plant firms source on average 23 percent of their inputs per season from wooden boats, while the largest firms (with 8 or more plants) source 33 percent on average per season.

[44] For example, consider a regression of the share of high quality output at the plant level on the average share of high quality output of other plants in the port, controlling for month and plant fixed effects, as well as the presence of independent suppliers. If a given plant's output quality and that of other plants were perfectly positively or negatively correlated across time, the coefficient on the average share of high quality output of other plants in the port would be respectively one and minus one. We find a coefficient of 0.04, with a standard error of 0.080.

The first stage, shown in Appendix Table A7, is strong: the number of wooden (or independent) boats supplying other plants in the port is highly correlated with the share of integrated supply to the plant in question during the same period. The sign is negative, suggesting that—even using our leave-out proxy—the availability of independent suppliers influences Share VI in the manner we expect. A plant substitutes towards integrated suppliers when independent suppliers are relatively scarce, and vice versa.

Results from the IV specifications are in columns 3-6 of Table 6. The IV estimates are larger in magnitude, but of the same sign and statistical significance as the corresponding OLS estimates. This holds whether we restrict attention to suppliers that are independent by law or include all independent suppliers. Additionally, the same is true in a similar, but not identical, specification show in Appendix Table A6, which utilizes internal data from the firm that shared its data with us.

We also supplement this with a robustness exercise which exploits persistence in boat locations, that is, the tendency for boats to remain in the same port for multiple trips. Specifically, we instrument for Share VI with the lagged presence of independent or wooden suppliers. To construct this measure for each port in month t, we first record the port of delivery for each boat in the last trip conducted in month $t-1$.[45] We then count the total number of boats present in each port. Both the estimated first and second stage results, shown in columns 1 and 2 of Appendix Table A8, are consistent with columns 4 and 6 of Table 6, though the second stage results are less precisely estimated. While this robustness exercise is subject to some of the same potential criticisms as our primary specification, this instrument will be valid even if our assumption (i) above is violated, so long as confounding plant-level actions are not autocorrelated. Similarly, this instrument will be valid even if (ii) above is violated, so long as relevant port-level shocks are not autocorrelated.

7.3 Instrumenting with windspeed and cloudiness

It is clearly possible to envision particular port level shocks (or equilibrium responses to a given plant's actions) that cause the exclusion restriction of the IV presented in the previous subsection to fail. To address this, we conclude our analysis with an alternative IV strategy that exploits port-level weather conditions. Of course, weather variables are not inherently perfect instruments in this context. It is possible, for example, that some variation in weather might influence the relative share of VI suppliers at a given port while simultaneously directly influencing the quality of fishmeal (e.g. by changing the location of the fish themselves). However, we focus specifically on two dimensions of weather conditions that plausibly influence the share of VI suppliers without impacting the underlying fish quality: windspeed and cloudiness. Our rationale is that the smaller wooden and independent boats might be less likely to fish in a port experiencing severe weather, as captured by these variables.

The National Oceanic and Atmospheric Administration (NOAA) provides monthly data at a 1×1 degree level on several aspects of the distribution of these two variables.[46] Given that there is no theoretical model predicting exactly how windspeed and cloudiness should correlate with a plant's use of integrated suppliers, and that the available moments of these variables individually has little predictive power, we take a predictive approach to the first stage. That is, we project Share VI onto all available aspects of the

[45] If no trip was conducted in $t-1$, we select the first trip of month t. For brevity, we omit specifications that do not control for *Has high technology*.

[46] Our weather data is drawn from the Monthly International Comprehensive Ocean-Atmosphere Dataset (ICOADS) provided by the NOAA, with spatial coverage based upon 1 degree by 1 degree boxes. Cloudiness refers to total cloudiness measured in okras. Windspeed refers to scalar wind measured in 0.01 m/s.

distributions of cloudiness and windspeed, as well as their interactions. If $\mathbf{z}_i$ is a vector containing the mean, median, bottom and top sextiles and standard deviation of both cloudiness and windspeed, and $\otimes$ represents the Kronecker product, we estimate as a first stage (for plant i in month t):

$$VI_{it} = \gamma_0 + (\mathbf{z}_i \otimes \mathbf{z}_i)'\Gamma + \gamma_1 \text{HighTech}_{it} + \eta_i + \theta_t + \varepsilon_{it} \tag{6}$$

Here η_i and θ_t are plant and month fixed effects, and $HighTech_{it}$ is an indicator equal to one if the plant has high technology, as above.

The results from our weather-based IV approach in columns 7 and 8 of Table 6 show an increase in output quality with greater use of integrated suppliers that is very similar in magnitude to the OLS and independent boat-presence IV results in columns 1-6 and marginally significant.[47] In Appendix Table A8 we show basic versions of this approach to provide transparency on the strategy and to confirm that our results are not driven by our saturated approach to the first stage. In columns 3 and 4 we include first the full set of windspeed variables and then the full set of cloudiness variables. The second stage results are consistent in magnitude with the range of our OLS and IV results. In column 5, we include the full set of windspeed and cloudiness variables. With this full set, we again see a coefficient that is consistent in magnitude with our original IV. Though these simpler versions of the weather-based instrument are weak instruments, the patterns in Appendix Table A8 provide support for our interpretation of the full equation (6) estimates in columns 7 and 8 of Table 6.

7.4 Interpretation

Our interpretation of the results presented in this section is that access to inputs from integrated suppliers directly increases output quality. In conjunction with the model in Section 3 and the results in Section 6, our analysis suggests that this is because a manufacturer can incentivize integrated suppliers to reduce behaviors that decrease quality.

Of course, output quality may in principle co-vary with organizational structure without an underlying causal relationship. Perhaps the most plausible non-causal link between quality upgrading and integration—that firm level level shocks or factors (e.g. overall growth), cause firms to simultaneously and independently produce higher quality output and acquire more suppliers—is ruled out by the simple OLS regressions in Table 6 and Appendix Table A6: output quality correlates with the *use* of integrated suppliers at the time of production across *plants*, including within firms.

While each of our IV strategies is subject to potential criticism, the results go a step further by demonstrating that the same relationships hold when we restrict attention to (i) the local presence of independent or wooden suppliers, (ii) the lagged presence of independent or wooden suppliers, or (iii) port level variation in windspeed and cloud cover. The consistency of our results across these approaches reinforces our basic OLS results.

Combining these findings with those found in Section 5, we conclude that it is not the case that higher output quality in vertically integrated Peruvian fishmeal manufacturers is simply an ignored by-product of integration decisions made for other reasons, nor that integration and output quality are causally unrelated in the "minds" of the firms in our sample. Our evidence here and in Table 3 suggests that integration is

[47] We omit the first stage for columns 7 and 8 given the large number of interactions.

an effective strategy for producing high quality output, that is, particular plants or firms that interact with integrated suppliers are able to produce higher quality output. In Section 5 we showed that increasing output quality is an explicit motive for integration. In other words, our evidence indicates that vertical integration increases output quality and that, as a result, firms integrate suppliers when they intend to increase the quality of the goods they produce.

8 Conclusion

This paper identifies an overlooked motivation for—and consequence of—vertical integration in incomplete contracts settings, namely downstream firms integrating to be able to produce output of high enough quality to sell to high-paying consumers abroad. We first present a simple theoretical framework that captures how suppliers and the downstream firms they supply are expected to behave in sectors where firms produce vertically differentiated goods and contracts are incomplete. The model motivates three predictions that follow logically from each other: on how the quality premium—the difference between the price of high and low quality output—affects firms' choice of organizational structure; how suppliers' behavior changes with integration; and how integration consequently affects output quality.

We test these predictions using transaction level data and direct measures of the quality grades manufacturers produce in Peru's fishmeal industry. We show that, when the returns to shifting from low to high quality production rise for exogenous reasons, firms acquire more of their suppliers. This strategy appears to be effective because integration allows firms to incentivize input quality-increasing behavior from their suppliers: fishing boats change their behavior in a way consistent with delivering fresher fish when they are acquired by the firm they supply—which is known to enable production of higher quality fishmeal. Finally, we show that firms ultimately produce higher quality output when their organizational structure is more vertically integrated. The evidence we present thus suggests that—while firms vertically integrate for many different reasons—one motive for integration is quality upgrading. That is, in settings like the one we study, integration is an explicit organizational choice made *in order to* "climb" the quality ladder.

A natural next question is the generality of this finding. Theory suggests that integration can help address contracting problems that are typical when input quality is difficult to observe (and hence incentivize), as is often the case. Despite vertical integration *overall* being common in developing countries (Acemoglu *et al.* , 2005; Macchiavello, 2011), it *may* thus be that the extent of vertical integration observed among firms in the developing world is actually suboptimally *low*, since upgrading output quality is essential for export-driven economic development. Of course, in a world with perfect contracting, there might be no need for integration. As such, our paper's results conversely imply that improvements in contract enforcement may reduce the need for firms to rely on organizational structure to align their suppliers' incentives.

References

ACEMOGLU, D., AGHION, P., GRIFFITH, R., & ZILIBOTTI, F. 2010. Vertical Integration and Technology: Theory and Evidence. *Journal of European Economic Association*, **8**(5).

ACEMOGLU, DARON, JOHNSON, SIMON, & MITTON, TODD. 2005. *Determinants of Vertical Integration: Finance, Contracts, and Regulation*. NBER working paper no. 11424.

ACEMOGLU, DARON, AGHION, PHILIPPE, LELARGE, CLAIRE, REENEN, JOHN VAN, & ZILIBOTTI, FABRIZIO. 2007. Technology, Information, and the Decentralization of the Firm. *The Quarterly Journal of Economics*, **122**(4), 1759–1799.

ALFARO, LAURA, CONCONI, PAOLA, FADINGER, HARALD, & NEWMAN, ANDREW F. 2016. Do Prices Determine Vertical Integration? *The Review of Economic Studies*, **83**(3), 855–888.

AMODIO, FRANCESCO, & MARTINEZ-CARRASCO, MIGUEL A. 2018. Input Allocation, Workforce Management and Productivity Spillovers: Evidence from Personnel Data. *Review of Economic Studies*, **85**(4), 1937–1970.

ATALAY, ENGHIN, HORTACSU, ALI, & SYVERSON, CHAD. 2014. Vertical Integration and Input Flows. *American Economic Review*, **104**(4), 1120–48.

ATKIN, DAVID, KHANDELWAL, AMIT, & OSMAN, ADAM. 2017. Exporting and Firm Performance: Evidence from a Randomized Experiment. *Quarterly Journal of Economics*, **132**(2).

BAKER, GEORGE, GIBBONS, ROBERT, & MURPHY, KEVIN J. 2001. Bringing the Market Inside the Firm? *American Economic Review*, **91**(2), 212–218.

BAKER, GEORGE, GIBBONS, ROBERT, & MURPHY, KEVIN J. 2002. Relational Contracts and the Theory of the Firm. *The Quarterly Journal of Economics*, **117**(1), 39–84.

BAKER, GEORGE P., & HUBBARD, THOMAS N. 2003. Make Versus Buy in Trucking: Asset Ownership, Job Design and Information. *American Economic Review*, **93**(3), 551–572.

BAKER, GEORGE P., & HUBBARD, THOMAS N. 2004. Contractibility and Asset Ownership: On-Board Computers and Governance in US Trucking. *Quarterly Journal of Economics*, **119**(4), 1443–1479.

BALDWIN, RICHARD., & HARRIGAN, JAMES. 2011. Zeros, Quality, and Space: Trade Theory and Trade Evidence. *American Economic Journal: Microeconomics*, **3**(2), 60–88.

BANERJEE, A., & DUFLO, E. 2000. Reputation Effects and the Limits of Contracting: A Study of the Indian Software Industry. *Quarterly Journal of Economics*, **115**(3), 989–1017.

BASTOS, PAULO, SILVA, JOANA, & VERHOOGEN, ERIC. 2018. Export Destinations and Input Prices. *American Economic Review*, **108**(2), 353–92.

BOEHM, JOHANNES. 2018. *The Impact of Contract Enforcement Costs on Value Chains and Aggregate Productivity*. mimeo, Sciences Po.

BRAMBILLA, IRENE, & PORTO, GUIDO. 2016. High-Income Export Destinations, Quality and Wages. *Journal of International Economics*, **98**(1), 21–35.

BRAMBILLA, IRENE, LEDERMAN, DANIEL, & PORTO, GUIDO. 2012. Exports, Export Destinations, and Skills. *American Economic Review*, **102**(7), 3406–38.

BRAMBILLA, IRENE, LEDERMAN, DANIEL, & PORTO, GUIDO. 2019. Exporting Firms and the Demand for Skilled Tasks. *Canadian Journal of Economics*, **52**(2), 763–783.

BRESNAHAN, TIMOTHY F., & LEVIN, JONATHAN D. 2013. Vertical integration and Market Structure. *In:* GIBBONS, R., & ROBERTS, D.J. (eds), *Handbook of Organizational Economics*. Princeton University Press.

BREZA, EMILY, & LIBERMAN, ANDRES. 2017. Financial Contracting and Organizational Form: Evidence from the Regulation of Trade Credit. *Journal of Finance*, **72**(1), 291–324.

COASE, RONALD H. 1937. The Nature of the Firm. *Economica*, **4**(16), 386–405.

DE LA PUENTE, OSCAR, SUEIRO, JUAN CARLOS, HECK, CARMEN, SOLDI, GIULIANA, & PUENTE, SANTIAGO DE LA. 2011. *Evaluacion de los sistemas de gestion pesquera en el marco de la certificacion a cargo del marine. La pesqueria Peruana de anchoveta*. Stewardship Council, Cayetano Heredia University WP.

EUROPEAN COMMISSION. 2018. *European Commission: Fishing Quotas*. https://ec.europa.eu/fisheries/cfp/fishing_rules/tacs_en.

FAO. 1986. *The production of fish meal and oil*. FAO Fisheries Technical Paper: 142.

FORBES, SILKE, & LEDERMAN, MARA. 2009. Adaptation and Vertical Integration in the Airline Industry. *American Economic Review*, **99**(5), 1831–49.

FORBES, SILKE J., & LEDERMAN, MARA. 2010. Does vertical integration affect firm performance? Evidence from the airline industry. *The RAND Journal of Economics*, **41**(4), 765–790.

FOSTER, LUCIA, HALTIWANGER, JOHN, & SYVERSON, CHAD. 2008. Reallocation, Firm Turnover, and Efficiency: Selection on Productivity or Profitability? *American Economic Review*, **98**(1), 394–425.

FRÍAS, JUDITH A., KAPLAN, DAVID S., & VERHOOGEN, ERIC A. 2009. *Exports and Wage Premia: Evidence from Mexican Employer-Employee Data*. mimeo Instituto Mexicano del Seguro Social.

GIBBONS, R., & ROBERTS, D.J. 2013. *Handbook of Organizational Economics*. Princeton University Press.

GIBBONS, ROBERT. 2005a. Four formal(izable) theories of the firm? *Journal of Economic Behavior and Organization*, **58**(2), 200 – 245.

GIBBONS, ROBERT. 2005b. Incentives Between Firms (and Within). *Management Science*, **51**(1), 1–150.

GIL, R. 2009. Revenue sharing distortions and vertical integration in the movie industry. *Journal of Law, Economics, and Organization*, **25**(2), 579–610.

GIL, R., & KIM, M. 2016. *Does Competition Increase Quality? Evidence from the US Airline Industry*. mimeo, Carey School of Business.

GIL, R., KIM, M., & ZANARONE, G. 2016. *The Value of Relational Adaptation in Outsourcing: Evidence from the 2008 shock to the US Airline Industry*. mimeo, Carey School of Business.

GOLDBERG, PINELOPI K, & PAVCNIK, NINA. 2007. Distributional Effects of Globalization in Developing Countries. *Journal of Economic Literature*, **45**, 39–82.

GOLDSMITH-PINKHAM, PAUL, SORKIN, ISAAC, & SWIFT, HENRY. 2019. *Bartik Instruments: What, When, Why, and How*. Mimeo, Yale University.

GROSSMAN, SANFORD J., & HART, OLIVER D. 1986. The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration. *Journal of Political Economy*, **94**(4), 691–719.

HALLAK, JUAN CARLOS. 2006. Product Quality and the Direction of Trade. *Journal of International Economics*, **68**(1), 238–265.

HALLAK, JUAN CARLOS, & SCHOTT, PETER. 2011. Estimating Cross-Country Differences in Product Quality. *Quarterly Journal of Economics*, **126**(1), 417–474.

HALPERN, LÁSZLÓ, KOREN, MIKLÓS, & SZEIDL, ADAM. 2015. Imported Inputs and Productivity. *American Economic Review*, **105**(12), 3660–3703.

HART, OLIVER, & MOORE, JOHN. 1990. Property Rights and the Nature of the Firm. *Journal of Political Economy*, **98**(6), 1119–1158.

HART, OLIVER, SHLEIFER, ANDREI, & VISHNY, ROBERT W. 1997. The proper scope of government: theory and an application to prisons. *The Quarterly Journal of Economics*, **112**(4), 1127–1161.

HOLMSTROM, B. 1999. The Firm as a Subeconomy. *Journal of Law, Economics, and Organization*, **15**(1), 74–102.

HOLMSTROM, B., & MILGROM, P. 1994. The firm as an incentive system. *American Economic Review*, **84**(4), 972–991.

HOLMSTROM, B., & TIROLE, J. 1991. Transfer pricing and organizational form. *Journal of Law, Economics, and Organization*, **7**(2), 201–229.

HOLMSTROM, BENGT, & MILGROM, PAUL. 1991. Multitask principal-agent analyses: Incentive contracts, asset ownership, and job design. *Journal of Law, Economics, & Organization*, **7**, 24–52.

HORTACSU, ALI, & SYVERSON, CHAD. 2007. Cementing Relationships: Vertical Integration, Foreclosure, Productivity, and Prices. *Journal of Political Economy*, **115**(2), 250–301.

HUMMELS, DAVID, & KLENOW, PETER J. 2005. The Variety and Quality of a Nation's Exports. *American Economic Review*, **95**(3), 704–723.

IFFO. 2014. *Chile fishing quotas set and landing information certification*. http://www.iffo.net/node/544.

IRF. 2017. *Catch quotas for 2017/2018 in accordance with scientific advice*. https://www.responsiblefisheries.is/news-and-media/news/catch-quotas-for-2017-2018-in-accordance-with-scientific-advice/328/.

JOHNSON, ROBERT C. 2012. Trade and Prices with Heterogeneous Firms. *Journal of International Economics*, **86**(1), 43–56.

KHANDELWAL, AMIT. 2010. The Long and Short (of) Quality Ladders. *The Review of Economic Studies*, **77**(4), 1450–1476.

KOSOVÁ, RENÁTA, LAFONTAINE, FRANCINE, & PERRIGOT, ROZENN. 2013. Organizational Form and Performance: Evidence from the Hotel Industry. *Review of Economics and Statistics*, **95**(4), 1303–1323.

KUGLER, MAURICE, & VERHOOGEN, ERIC. 2012. Prices, Plant Size, and Product Quality. *Review of Economic Studies*, **79**(1), 307–339.

LAFONTAINE, FRANCINE, & SLADE, MARGARET. 2007. Vertical Integration and Firm Boundaries: The Evidence. *Journal of Economic Literature*, **45**(3), 629–685.

LEGROS, PATRICK, & NEWMAN, ANDREW F. 2013. A Price Theory of Vertical and Lateral Integration. *Quarterly Journal of Economics*, **128**(2), 725–770.

MACCHIAVELLO, ROCCO. 2011. Financial development and vertical integration: theory and evidence. *Journal of the European Economic Association*, **10**(2), 255–289.

MACCHIAVELLO, ROCCO, & MIQUEL-FLORENSA, JOSEPA. 2016. *Vertical Integration and Relational Contracts: Evidence from Costa Rica's Coffee Chain*. Mimeo LSE.

MACCHIAVELLO, ROCCO, & MORJARIA, AMEET. 2015. The Value of Relationships: Evidence from a Supply Shock to Kenya Rose Exports. *American Economic Review*, **105**(9), 2911–45.

MANOVA, KALINA, & ZHANG, ZHIWEI. 2012. Export Prices Across Firms and Destinations. *The Quarterly Journal of Economics*, **127**(1), 379–436.

MARTINEZ-CARRASCO, JOSE. 2017. *Coordination and Gains from Relational Contracts: Evidence from the Peruvian Anchovy Fishery*. Mimeo, Duke University.

MCMILLAN, JOHN, & WOODRUFF, CHRISTOPHER. 1999. Interfirm Relationships and Informal Credit in Vietnam. *Quarterly Journal of Economics*, **114**(4), 1285–1320.

MEDINA, PAMELA. 2017. *Import Competition, Quality Upgrading and Exporting: Evidence from the Peruvian Apparel Industry*. Mimeo, University of Toronto.

MULLAINATHAN, S., & SHARFSTEIN, D. 2001. Do firm boundaries matter? *American Economic Review, P&P*, **91**(2), 1995–1999.

NATIVIDAD, GABRIEL. 2014. Integration and Productivity: Satellite-Tracked Evidence. *Management Science*, **60**(7), 1698–1718.

NOVAK, SHARON, & STERN, SCOTT. 2008. How Does Outsourcing Affect Performance Dynamics? Evidence from the Automobile Industry. *Management Science*, **54**(12), 1963–1979.

NUNN, NATHAN. 2007. Relationship-Specificity, Incomplete Contracts, and the Pattern of Trade. *The Quarterly Journal of Economics*, **122**(2), 569–600.

ORDOVER, JANUSZ A., SALONER, GARTH, & SALOP, STEVEN C. 1990. Equilibrium vertical foreclosure. *American Economic Review*, **80**(1), 127–142.

PAREDES, E. CARLOS, & GUTIERREZ, MARIA E. 2008. *The Peruvian Anchovy Sector: Costs and Benefits. An analysis of recent behavior and future challenges*. IIFET 2008 Vietnam Proceedings.

PARK, ALBERT, YANG, DEAN, SHI, XINZHENG, & JIANG, YUAN. 2010. Exporting and Firm Performance: Chinese Exporters and the Asian Financial Crisis. *Review of Economics and Statistics*, **92**(4).

PIGOU, ARTHUR C. 1912. *Wealth and Welfare*. London: Macmillan.

SCHOTT, PETER K. 2004. Across-product versus within-product specialization in international trade. *The Quarterly Journal of Economics*, **119**(2), 647–678.

SUTTON, J. 1991. *Sunk Costs and Market Structure: Price Competition, Advertising, and the Evolution of Concentration*. MIT Press.

SUTTON, J. 1998. *Technology and Market Structure: Theory and History*. MIT Press.

SYVERSON, CHAD. 2004. Product Substitutability and Productivity Dispersion. *The Review of Economics and Statistics*, **86**(2), 534–550.

TANOUE, WATARU. 2015. *Japan's Total Allowable Catch Systems in Fishery Resource Management*. https://digital.lib.washington.edu/researchworks/bitstream/handle/1773/34012/Tanoue_washington_0250O_14735.pdf?sequence=1&isAllowed=y.

TINTELNOT, FELIX, MOGSTAD, KEN KIKKAWA MAGNE, & DHYNE, EMMANUEL. 2017. *Trade and Domestic Production Networks*. Mimeo, Chicago University.

TVETERAS, SIGBJORN, PAREDES, CARLOS E., & TORRES, JULIO PENA. 2011. Individual Vessel Quotas in Peru: Stopping the Race for Anchovies. *Marine Resource Economics*, **26**, 225–232.

VERHOOGEN, ERIC A. 2008. Trade, Quality Upgrading, and Wage Inequality in the Mexican Manufacturing Sector. *The Quarterly Journal of Economics*, **123**(2), 489–530.

WILLIAMSON, OLIVER. 1971. The Vertical Integration of Production: Market Failure Considerations. *The American Economic Review*, **61**(2), 112–123.

WOODRUFF, CHRISTOPHER. 2002. Non-contractible Investments and Vertical Integration in the Mexican Footwear Industry. *International Journal of Industrial Organization*, **20**(8), 1197–1224.

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: SUMMARY STATISTICS ON INTEGRATION

Panel A: Boat purchases and sales	
Total number of steel boats registered	741
Number of steel boat transactions	317
Number of transactions Indep. → VI	103
Number of transactions VI → Indep.	32
Number of transactions VI → VI	50
Number of transactions Indep. → Indep.	132

Panel B: Variance decomposition of changes in share of inputs from VI suppliers

	VI extensive margin (Boat purchases or sales)	VI intensive margin (Intensity of use of own VI suppliers)	Indep. margin (Buying less/more from Indep.)
	(1)	(2)	(3)
Contribution	35%	16%	49%

Notes: Panel A displays basic statistics on boat purchases and sales. Only steel boats can be owned by downstream firms. Panel B presents a variance decomposition of the three margins by which a firm can change its share of inputs from VI suppliers over time. The *VI extensive margin* corresponds to the change in the variable due to the firm buying or selling boats. The *VI intensive margin* corresponds to changes in the own use share of all the inputs produced by VI suppliers. VI suppliers sometimes supply other firms (around 10% of the time - see Figure 1) so a firm could decide to take in more or less of its VI suppliers inputs. The last contribution is the *Indep. margin* which corresponds to the firm buying more or less from independent boats than in the previous season which mechanically impacts the share of inputs from VI suppliers. Appendix B provides the computational details of the decomposition and how the variance decomposition is done in practice.

TABLE 3: OUTPUT QUALITY AND VERTICALLY INTEGRATED SUPPLIERS

Panel A: Output quality and number of suppliers owned

Dep. var:	High Quality share of prod.		Protein content	
	(1)	(2)	(3)	(4)
Asinh(Number of Suppliers Owned)	0.057	0.045	0.227***	0.171**
	(0.060)	(0.041)	(0.072)	(0.080)
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.	0.75	0.75	65.7	65.7
N	275	275	208	208
R^2	0.75	0.81	0.79	0.80

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

Dep. var:	High Quality share of prod.		Protein content	
	(1)	(2)	(3)	(4)
Share of inputs from VI suppliers	0.311**	0.284**	1.157***	1.153***
	(0.124)	(0.118)	(0.276)	(0.285)
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.	0.75	0.75	65.7	65.7
N	275	275	208	208
R^2	0.76	0.81	0.79	0.80

Panel C: Output quality and Share of inputs from VI suppliers

Dep. var:	High Quality share of prod.			Protein Content		
	(1)	(2)	(3)	(4)	(5)	(6)
Share of inputs from VI suppliers	0.269**	0.302**	0.288**	1.185***	1.146***	1.101***
	(0.113)	(0.121)	(0.116)	(0.350)	(0.281)	(0.289)
Share of inputs from steel boats	−0.161		−0.155	−0.702		−0.593
	(0.205)		(0.195)	(0.962)		(0.797)
Share of inputs from boats with high capacity	0.254		0.242	0.847		0.983
	(0.218)		(0.213)	(1.315)		(1.129)
Share of inputs from boats with cooling system	0.090		0.100	−0.176		−0.097
	(0.120)		(0.120)	(0.845)		(0.706)
Share of industry's production		−0.405	−0.324		−1.124	−1.032
		(1.069)	(1.024)		(3.663)	(3.684)
Log(production)		−0.023	−0.023		0.322	0.345
		(0.032)	(0.031)		(0.301)	(0.306)
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.	0.75	0.75	0.75	65.7	65.7	65.7
N	275	275	275	208	208	208
R^2	0.82	0.82	0.82	0.80	0.81	0.81

Notes: One observation is a firm during a production season. *High Quality share of prod.* is the share of a firm's total production during a fishing season that is reported as high quality ("prime") output. This dependent variable is available for 34 firms over 14 fishing seasons from April 2009 to November 2016. *Protein content* is the quantity weighted average of a measure of quality inferred from a database that provides weekly prices by quality. This dependent variable is available for 23 firms over 15 fishing seasons from April 2009 to April 2017. We observe one more fishing season for this dependent variable than for *High Quality share of prod.* The number of individual firms is smaller for the second dependent variable as we do not observe export transactions for 11 firms. *Share of inputs from VI suppliers* is the share of a firm'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 must use ice to keep fish fresh. *Share of industry's production* is a firm's total production of fishmeal during a given season divided by the industry's total production on that season. *Log(production)* is the logarithm of a firm's total production during a given 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. Standard errors clustered at the firm level are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

TABLE 4: VERTICAL INTEGRATION AND THE QUALITY PRICE PREMIUM

Dep. var:	Share of inputs from VI suppliers (t) - Share of inputs from VI suppliers (t-1)									
	OLS	OLS	OLS	OLS	OLS	OLS	IV	IV	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Quality premium	0.147^{*}		0.158^{*}							
	(0.082)		(0.089)							
Quality premium is high		0.014^{**}								
		(0.006)								
Quality premium is low		-0.007								
		(0.010)								
Log(average price)				0.057						
				(0.043)						
Upgradable share of production (t-1) × Quality premium					2.709^{***}		2.536^{***}		2.712^{***}	
					(0.397)		(0.569)		(0.398)	
Low quality producer (t-1) × Quality premium						0.920^{**}		0.621		0.978^{**}
						(0.425)		(0.498)		(0.418)
Upgradable share of production (t-1)	No	No	No	No	Yes	No	Yes	No	Yes	No
Low quality producer (t-1)	No	No	No	No	No	Yes	No	Yes	No	Yes
Season FEs	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Firm FEs	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean of Dep. Var.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N	191	191	191	191	191	191	191	191	191	191
R^2	0.01	0.02	0.08	0.07	0.24	0.21	0.24	0.20	0.24	0.21
Quality prem. is high = Quality prem. is low (p-val)		0.09								

First stage	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Upgradable share of production (t-1) × Log(Quota Chile) (t-1)							-1.153^{**}			
							(0.457)			
Upgradable share of production (t-1) × Log(Quota Denmark) (t-1)							-6.111^{**}			
							(2.775)			
Upgradable share of production (t-1) × Log(Quota Iceland) (t-1)							-1.542^{**}			
							(0.700)			
Low quality producer (t-1) × Log(Quota Chile) (t-1)								-0.923^{***}		
								(0.196)		
Low quality producer (t-1) × Log(Quota Denmark) (t-1)								-4.790^{***}		
								(1.257)		
Low quality producer (t-1) × Log(Quota Iceland) (t-1)								-1.223^{***}		
								(0.317)		
Upgradable share of production (t-1) × Log(Chile Price)									1.081^{***}	
									(0.135)	
Upgradable share of production (t-1) × Log(Denmark Price)									-2.950^{***}	
									(0.740)	
Upgradable share of production (t-1) × Log(Iceland Price)									1.469^{**}	
									(0.558)	
Low quality producer (t-1) × Log(Chile Price)										1.175^{***}
										(0.044)
Low quality producer (t-1) × Log(Denmark Price)										-2.158^{***}
										(0.534)
Low quality producer (t-1) × Log(Iceland Price)										0.667
										(0.486)
Kleibergen-Paap LM p-value (under-id)							0.01	0.07	0.01	0.06
Kleibergen-Paap Wald F statistic (weak inst)							37.6	22.1	30.4	471.2

Notes: One observation is a firm during a production season. *Share of inputs from VI suppliers (t) - Share of inputs from VI suppliers* $(t-1)$ is the change between season $t-1$ and season t of the share of inputs sourced from integrated suppliers. Our sample includes 24 unique firms over 12 unique fishing seasons from November 2010 to November 2016. The number of seasons is smaller than in Table 3 as the price data is only available from 2010 onwards. The number of unique firms is also smaller as several small firms die in 2009 and 2010. As shown in Table 2, most of the variation in Share VI is driven by acquisition or sales of suppliers. *Quality premium* is equal to $Log(\text{High Quality}) - Log(\text{Low Quality})$ where High and Low Quality are the average price of "Prime" and "FAQ" fishmeal in the month preceding the current fishing season. We choose to take the month preceding the fishing season rather than the fishing season itself as integration decisions are typically decided in the month preceding the season and integration within a season is extremely rare in the data. *High Quality premium* (*Low Quality premium*) is equal to 1 if the Quality Premium is above (below) the sample average value. $Log(\text{average price})$ is the Log of the average price of Peruvian fishmeal, again computed in the month preceding the current fishing season. Low quality producer$(t-1)$ is equal to 1 if a firm's share of low quality output in the preceding season was at least 1 percent. Upgradable share of production$(t-1)$ is the share of a firm's production that was of low quality in the previous season. A firm that produces almost exclusively low quality output has more potential to upgrade than a firm already producing almost exclusively high quality output. In Columns 7 and 8, the instruments are interactions between Low quality producer$(t-1)$ or Upgradable share of production$(t-1)$ and the fishing quota of top high quality fishmeal exporters. 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

Panel A: Identified from all switchers (Independent to VI, VI to Independent and 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]	-0.096^{***}	-0.053^{***}	-0.030^{*}
	(0.023)	(0.019)	(0.016)
Date FEs	Yes	Yes	Yes
Supplier × Plant FEs	Yes	Yes	Yes
N	319,827	140,365	163,165
N distinct suppliers	1,149	1,081	1,081
R^2	0.62	0.42	0.34

Panel B: Identified only from VI switchers 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[Always VI × supplies owner firm]	-0.148^{***}	-0.077^{***}	-0.067^{***}
	(0.026)	(0.025)	(0.022)
Date FEs	Yes	Yes	Yes
Supplier × Plant FEs	Yes	Yes	Yes
N	319,827	140,365	163,165
N distinct suppliers	1,149	1,081	1,081
R^2	0.62	0.42	0.34

Panel C: Integration and Seasonal effort	
Dep. var:	Log(Number of trips per season)
	(1)
I[VI]	0.190^{***}
	(0.053)
Season FEs	Yes
Supplier FEs	Yes
N	12,992
N distinct suppliers	1,149
R^2	0.61

Notes: For panels A and B, one observation is a boat during a fishing trip. For panel C, one observation is a boat during a fishing season. *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. In panel A, we define I[VI×supplies owner firm] to be equal to one if the supplier is (i) currently vertically integrated (ii) currently delivering to its parent firm. In panel B, we define I[Always VI×supplies owner firm] to be equal to one if the supplier is (i) always owned by a fishmeal firm, and (ii) currently delivering to its parent firm. Because we include Supplier × Plant FEs, I[VI×supplies owner firm] and I[Always VI×supplies owner firm] are identified based only on suppliers who change ownership during our sample period. In these panels, columns (1), (2) and (3) reflect 1,749, 1,277, and 1,079 unique fishing days, respectively, covering the period from April 2009 to April 2017 for column (1), and from April 2009 to November 2015 for columns (2) and (3). In panel C, I[VI] is identified from boats that switch from independent to VI or VI to independent. This panel covers 16 unique fishing seasons from April 2009 to April 2018. Each column shows the total number of observations and total number of unique suppliers in the corresponding specification. The number of observations varies from one column to the next as GPS variables for a given trip are sometimes missing. Note that most of this missingness is within supplier, as GPS data is available for nearly all boats for at least for a portion of our sample. Standard errors clustered at the boat level are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 6: OUTPUT QUALITY AND SHARE OF INPUTS FROM VERTICALLY INTEGRATED SUPPLIERS

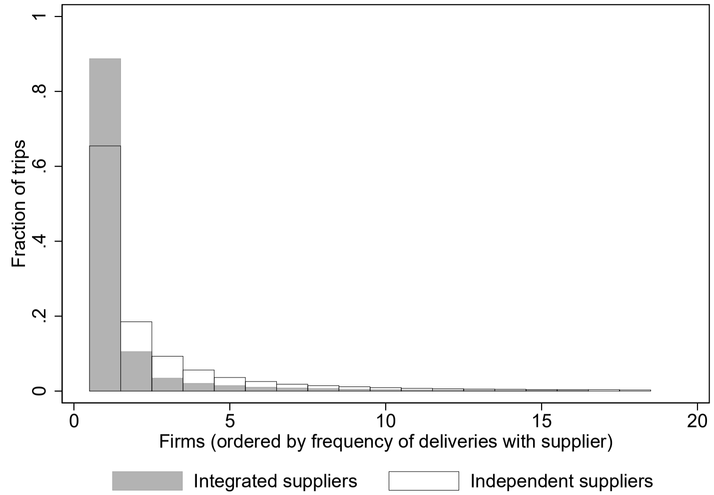
	Impact of Share of VI Inputs on Quality							
Dep. var:	High Quality Share of Production							
	OLS		IV: Ind. Boats		IV: Wooden Boats		IV: Weather	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Share of inputs from VI suppliers	0.102^{**}	0.064^{**}	0.165^{***}	0.139^{**}	0.160^{***}	0.142^{**}	0.102	0.094^{*}
	(0.037)	(0.029)	(0.056)	(0.059)	(0.055)	(0.069)	(0.069)	(0.056)
Has high technology	No	Yes	No	Yes	No	Yes	No	Yes
Month FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Plant FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean of Dep Var.	0.84	0.84	0.84	0.84	0.84	0.84	0.83	0.83
N	2,647	2,647	2,647	2,647	2,647	2,647	1,413	1,413
R^2	0.58	0.67	0.58	0.67	0.58	0.66	0.59	0.65

Notes: One observation is a plant in a particular month. *High Quality share of production* is the share of a plant's total production during a month that is reported as high quality "prime" output. *Share of inputs from VI suppliers* is the share of a plant's inputs that comes from VI suppliers during a month. *Has high technology* is a dummy variable equal to one if the plant in question has any steam-drying technologies installed. Columns 3 and 4 instrument for *Share of inputs from VI suppliers* with the number of independent boats present locally (in the plant's port) in the month in question, excluding those that interact directly with the plant itself. Columns 5 and 6 instrument for *Share of inputs from VI suppliers* with the number of wooden boats present locally (in the plant's port) in the month in question, excluding those that interact directly with the plant itself. Columns 7 and 8 instrument for *Share of inputs from VI suppliers* with the mean, median, 1st and 5th quintiles and standard deviation of monthly port-level cloudiness and wind speed as well as all interactions between these variables. Due to data availability weather instruments are only available for a subset of months. The sample in columns 1-6 include 94 unique plants in 79 unique months from April 2009 to June 2017. The sample in columns 7-8 include 88 unique plants in 62 unique months spanning April 2009 to December 2016. Standard errors are clustered at the port level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

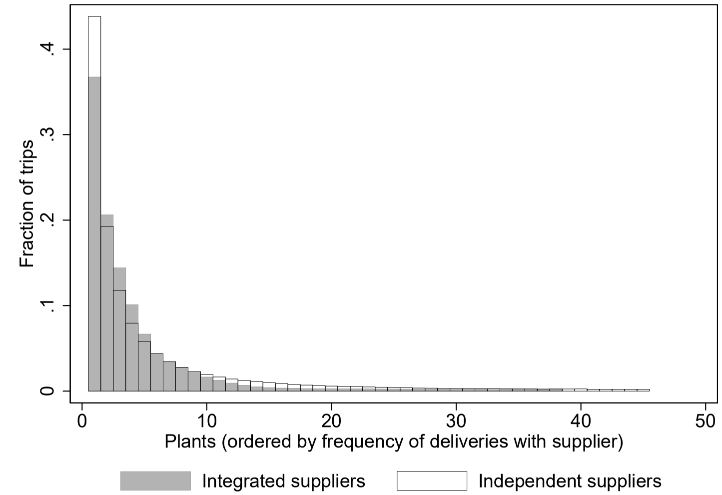
FIGURE 1: INTERACTIONS BETWEEN MANUFACTURERS AND INTEGRATED AND INDEPENDENT SUPPLIERS

All Suppliers

(a) Distribution of interactions across firms

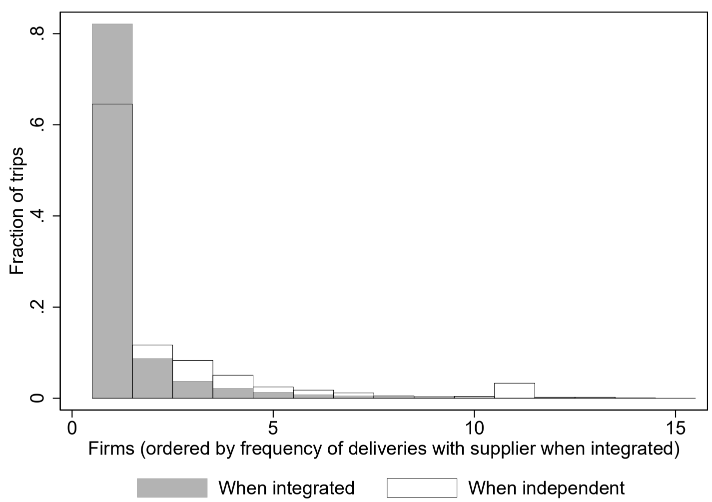


(b) Distribution of interactions across plants

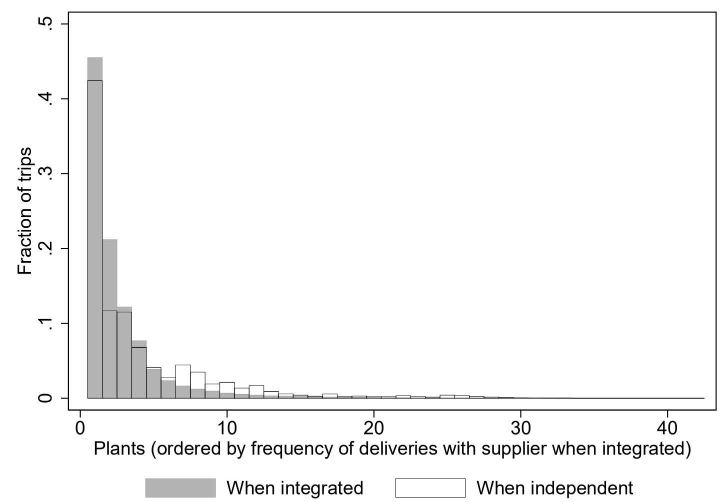


Switchers Only

(c) Distribution of interactions across firms

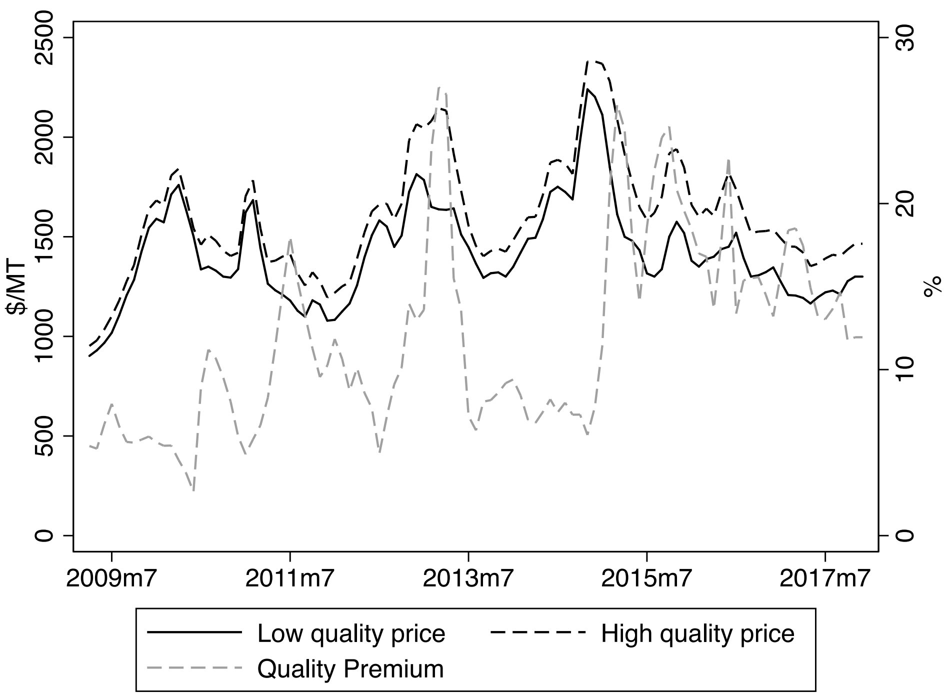


(d) Distribution of interactions across plants



Notes: Figures above show the average fraction of deliveries at each firm and plant for independent and integrated suppliers. In figures (a) and (b), plants or firms are ordered based on the frequency of deliveries for each boat x boat owner pair: the plant or firm that receives the highest number of deliveries by the boat in question while owned by the owner in question is ranked one, the next highest ranked two, and so on. In figures (c) and (d) plants or firms are ranked based on the frequency of deliveries for each boat *while it is integrated*. Figures (a) and (b) include all suppliers, while figures (c) and (d) include only *switchers*: boats that were independent at one point and integrated at another point during our sample.

FIGURE 2: AVERAGE FISHMEAL PRICE AND QUALITY PREMIUM IN PERU



Notes: This figure shows the evolution over time of the fishmeal prices in Peru (the price of "Prime" and "FAQ" fishmeal grades) and the Quality Premium in Peru. *Quality premium* is equal to $Log(\text{High Quality}) - Log(\text{Low Quality})$ where High and Low Quality are the average prices of "Prime" and "FAQ" fishmeal grades respectively.

Appendix A Additional Tables and Figures

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

	Total Weight (1000 metric tons)	Average Protein content	Sd(Protein content)
CHINA	4315	66.07	1.60
GERMANY	972	65.42	1.62
JAPAN	545	66.12	1.69
CHILE	308	66.60	1.51
VIETNAM	281	65.91	1.59
TAIWAN	250	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	67	65.76	1.52
FRANCE	55	65.59	1.72
SOUTH KOREA	25	66.56	1.46
ITALY	21	64.97	1.52
BULGARIA	16	65.42	1.75
VENEZUELA	13	66.67	1.64
PHILIPPINES	12	64.92	1.47
BELGIUM	11	65.08	1.69
INDIA	10	65.17	2.03

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: 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	56.11
	(16.24)	(0.06)	(27.34)	(94.78)	(7.74)
Steel - Independent	104.03	0.09	219.30	412.31	81.12
	(40.77)	(0.28)	(84.35)	(189.82)	(13.42)
Steel - Switchers	148.24	0.26	301.37	620.14	92.03
	(71.00)	(0.444)	(131.23)	(331.29)	(15.42)
Steel - VI	181.62	0.34	381.67	768.79	97.38
	(68.01)	(0.47)	(136.97)	(352.40)	(12.67)

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 A3: Vertical integration and the quality price premium – Robustness checks

Dep. var:	Share VI (t) - Share VI (t-1)		Share of inputs from VI suppliers							
	IV	IV	OLS	OLS	OLS	OLS	OLS	IV	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Upgradable share of production (t-1) × Quality premium	2.475^{***}	2.591^{***}					0.530	0.430	0.408	0.486
	(0.599)	(0.500)					(0.500)	(0.479)	(0.430)	(0.493)
Log(production) (t) - Log(production) (t-1)	0.001									
	(0.007)									
Quality premium			0.884^{**}		0.214					
			(0.373)		(0.233)					
Quality premium is high				0.471^{***}						
				(0.069)						
Quality premium is low				0.390^{***}						
				(0.073)						
Log(average price)						0.094				
						(0.089)				
Upgradable share of production (t-1)	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes
Season FEs	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes
Firm FEs	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Mean of Dep. Var.	0.00	0.00	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
N	191	191	205	205	205	205	205	205	205	205
R^2	0.24	0.24	0.02	0.63	0.89	0.89	0.90	0.90	0.90	0.90
Quality prem. is high = Quality prem. is low (p-val)				0.04						
First stage										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Upgradable share of production (t-1) × Log(Quota Chile) (t-1)	-1.083^{**}	-0.982^{***}						-1.627^{***}	-1.260^{***}	
	(0.436)	(0.297)						(0.168)	(0.163)	
Upgradable share of production (t-1) × Log(Quota Denmark) (t-1)	-5.646^{**}	-1.620						-8.968^{***}	-3.009	
	(2.644)	(1.879)						(1.124)	(1.773)	
Upgradable share of production (t-1) × Log(Quota Iceland) (t-1)	-1.419^{**}	-0.444						-2.267^{***}	-0.799^{*}	
	(0.666)	(0.472)						(0.281)	(0.439)	
Upgradable share of production (t-1) × Log(Qty exp. by Thailand) (t-1)		0.081^{***}							0.085^{***}	
		(0.021)							(0.016)	
Upgradable share of production (t-1) × Log(Chile Price)										1.179^{***}
										(0.023)
Upgradable share of production (t-1) × Log(Denmark Price)										-3.292^{***}
										(0.406)
Upgradable share of production (t-1) × Log(Iceland Price)										1.680^{***}
										(0.358)
Log(production) (t) - Log(production) (t-1)	0.002									
	(0.001)									
Kleibergen-Paap LM p-value (under-id)	0.01	0.02						0.01	0.01	0.00
Kleibergen-Paap Wald F statistic (weak inst)	22.2	44.7						431.6	806.9	1674.2

Notes: One observation is a firm during a production season. This Table provide robustness checks for Table 4. See notes at the bottom of Table 4 for the description of all variables. In columns 1 and 2, we control for changes in scale, with *Log(production) (t) - Log(production) (t-1)*, with is the change in the Log of total production between season t-1 and season t. In columns 3 and 4, the instruments are interactions between Low quality producer$(t-1)$ or Upgradable share of production$(t-1)$ and the price of fishmeal from the top high quality fishmeal exporters. Standard errors clustered at the firm level are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE A4: VERTICAL INTEGRATION AND THE QUALITY PRICE PREMIUM – LOGIT TRANSFORMATION

Dep. var:	Log(Share VI_t/[1-(Share VI_t)])- Log(Share VI_{t-1}/[1-(Share VI_{t-1})])									
	OLS	OLS	OLS	OLS	OLS	OLS	IV	IV	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Quality premium	0.533		0.382							
	(0.805)		(0.829)							
Quality premium is high		0.092**								
		(0.034)								
Quality premium is low		−0.019								
		(0.092)								
Log(average price)				0.062						
				(0.459)						
Upgradable share of production (t-1) × Quality premium					11.228***		14.329***		11.734***	
					(3.791)		(4.776)		(2.940)	
Low quality producer (t-1) × Quality premium						3.821*		6.218		4.580**
						(2.149)		(4.413)		(2.051)
Upgradable share of production (t-1)	No	No	No	No	Yes	No	Yes	No	Yes	No
Low quality producer (t-1)	No	No	No	No	No	Yes	No	Yes	No	Yes
Season FEs	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Firm FEs	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean of Dep. Var.	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
N	191	191	191	191	191	191	191	191	191	191
R^2	0.00	0.01	0.07	0.07	0.14	0.13	0.14	0.01	0.03	0.02

Notes: One observation is a firm during a production season. *Share* VI_t is the share of inputs sourced from integrated suppliers in season t. To compute Log(Share VI_t/[1-(Share VI_t)] for all observations, we add 0.01 to firm-seasons with Share VI equal to 0, and subtract 0.01 from firm-seasons with Share VI equal to 1. *Quality premium* is equal to $Log(\text{High Quality}) - Log(\text{Low Quality})$ where High and Low Quality are the average price of "Prime" and "FAQ" fishmeal in the month preceding the current fishing season. We choose to take the month preceding the fishing season rather than the fishing season itself as integration decisions are typically decided in the month preceding the season and integration within a season is extremely rare in the data. *High Quality premium* (*Low Quality premium*) is equal to 1 if the Quality Premium is above (below) the sample average value. $Log(\text{average price})$ is the Log of the average price of Peruvian fishmeal, again computed in the month preceding the current fishing season. Low quality producer$(t-1)$ is equal to 1 if a firm's share of low quality output in the preceding season was at least 1 percent. Upgradable share of production$(t-1)$ is the share of a firm's production that was of low quality in the previous season. A firm that produces almost only low quality output has more potential to upgrade than a firm already producing almost only high quality output. In Columns 7 and 8, the instruments are interactions between Low quality producer$(t-1)$ or Upgradable share of production$(t-1)$ and the fishing quota of top high quality fishmeal exporters. Standard errors clustered at the firm level are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A5: Individual instruments first stage from columns 9 and 10 in Table 4 and column 10 of Table A3

Dep. var:	Upgradable share of production (t-1) × Quality premium			Low quality producer (t-1) × Quality premium		
	(1)	(2)	(3)	(4)	(5)	(6)
Upgradable share of production (t-1) × Log(Chile Price)	0.299^{***} (0.033)					
Upgradable share of production (t-1) × Log(Denmark Price)		0.150^{***} (0.057)				
Upgradable share of production (t-1) × Log(Iceland Price)			0.128^{**} (0.050)			
Low quality producer (t-1) × Log(Chile Price)				0.377^{***} (0.063)		
Low quality producer (t-1) × Log(Denmark Price)					0.314^{**} (0.124)	
Low quality producer (t-1) × Log(Iceland Price)						0.266^{**} (0.108)
Upgradable share of production (t-1)	Yes	Yes	Yes	No	No	No
Low quality producer (t-1)	No	No	No	Yes	Yes	Yes
Season FEs	Yes	Yes	Yes	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes	Yes	Yes	Yes
N	205	205	205	205	205	205

Notes: One observation is a firm during a production season. This Table shows regressions equivalent to the first stage in column 9 and 10 of Table 4, except that each instrument is taken individually in each regression. See the table notes of Table 4 for more details on each variable. Standard errors clustered at the firm level are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE A6: OUTPUT QUALITY AND SHARE OF INPUTS FROM VERTICALLY INTEGRATED SUPPLIERS—ROBUSTNESS USING A SINGLE LARGE FIRM

	Impact of Share of VI Inputs on Quality			
Dep. var:	Protein Content			
	OLS		IV: Ind. Boats	
	(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)
Has high technology	No	Yes	No	Yes
Month FEs	Yes	Yes	Yes	Yes
Plant FEs	Yes	Yes	Yes	Yes
Mean of Dep Var.	65.8	65.8	65.8	65.8
N	66	66	66	66
R^2	0.82	0.82	0.82	0.82
	First Stage			
Dep. var:	Share of Inputs from VI Suppliers			
	(1)	(2)	(3)	(4)
Number of Independent Boats in Port (Leave-Out)			−0.000	−0.000
			(0.000)	(0.000)
Share of Independent Boats in Port (Leave-Out)			−0.412**	−0.398*
			(0.200)	(0.207)
Kleibergen-Paap LM p-value (Under-id)			0.005	0.006
Kleibergen-Paap Wald F statistic (Weak inst)			3.61	3.06

Notes: This table presents robustness checks for Table 6 using a major firm's internal data that allows us to link export sales to a specific plant. *Share of inputs from VI suppliers* is the share of a firm's inputs that come from VI suppliers during a season. *Has high technology* is a dummy variable equal to one if the plant in question has any steam drying technologies installed. *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. Robust standard errors are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE A7: OUTPUT QUALITY AND SHARE OF INPUTS FROM VERTICALLY INTEGRATED SUPPLIERS—FIRST STAGE

	First Stage			
Dep. var:	Share of Inputs from VI Suppliers			
	IV: Ind. Boats		IV: Wooden Boats	
	(1)	(2)	(3)	(4)
Number of Independent Boats in Port (Leave-Out)	-0.001^{***}	-0.001^{***}		
	(0.000)	(0.000)		
Number of Wooden Boats in Port (Leave-Out)			-0.002^{***}	-0.002^{***}
			(0.000)	(0.000)
Kleibergen-Paap LM p-value (Under-id)	0.009	0.009	0.010	0.009
Kleibergen-Paap Wald F statistic (Weak inst)	33.1	33.7	27.7	28.7

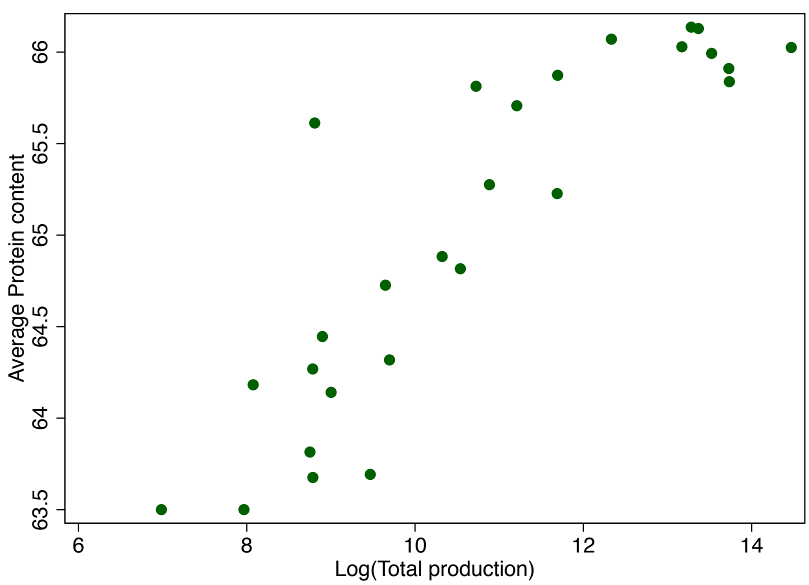
Notes: This table shows first stage results for columns 3-6 from Table 6. One observation is a plant in a particular month. *Share of inputs from VI suppliers* is the share of a plant's inputs that come from VI suppliers during a season. Columns 1 and 2 show the first stage instrumenting for *Share of inputs from VI suppliers* with the number of independent boats present locally (in the plant's port) in the season in question, excluding those that interact directly with the plant itself. Columns 3 and 4 show the first stage instrumenting for *Share of inputs from VI suppliers* with the number of wooden boats present locally (in the plant's port) in the season in question, excluding those that interact directly with the plant itself. Columns 2 and 4 include controls for *Has high technology*, a dummy variable equal to one if the plant in question has any steam drying technologies installed. Standard errors are clustered at the port level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE A8: OUTPUT QUALITY AND SHARE OF INPUTS FROM VERTICALLY INTEGRATED SUPPLIERS—ROBUSTNESS

	Impact of Share of VI Inputs on Quality				
Dep. var:	High Quality Share of Production				
	IV: Ind. Boats (t-1)	IV: Wooden Boats (t-1)	IV: Windspeed	IV: Cloudiness	IV: Windspeed and Cloudiness
	(1)	(2)	(3)	(4)	(5)
Share of Inputs from VI Suppliers	0.197 (0.141)	0.210 (0.140)	0.071 (0.334)	0.204 (0.209)	0.214 (0.162)
Has high technology	Yes	Yes	Yes	Yes	Yes
Month FEs	Yes	Yes	Yes	Yes	Yes
Plant FEs	Yes	Yes	Yes	Yes	Yes
Mean of Dep Var.	0.84	0.84	0.84	0.83	0.83
N	2,545	2,545	1,487	1,502	1,413
R^2	0.66	0.66	0.65	0.65	0.65
	First Stage				
Dep. var:	Share of Inputs from VI Suppliers				
	(1)	(2)	(3)	(4)	(5)
Independent Boats in Port (End of Month t-1)	-0.001^{***} (0.000)				
Wooden Boats in Port (End of Month t-1)		-0.001^{***} (0.000)			
Wind Speed (Mean)			-0.134^{**} (0.060)		-0.087 (0.078)
Wind Speed (Median)			0.021 (0.022)		-0.006 (0.030)
Wind Speed (Bottom Sextile)			0.072^{***} (0.027)		0.043 (0.034)
Wind Speed (Top Sextile)			0.029 (0.025)		0.044^{*} (0.027)
Wind Speed (Std. Dev.)			0.016 (0.018)		-0.015 (0.021)
Cloudiness (Mean)				0.151^{*} (0.080)	0.186^{*} (0.097)
Cloudiness (Median)				-0.051^{*} (0.030)	-0.071^{**} (0.035)
Cloudiness (Bottom Sextile)				0.004 (0.027)	-0.001 (0.030)
Cloudiness (Top Sextile)				-0.109^{***} (0.033)	-0.118^{***} (0.042)
Cloudiness (Std. Dev.)				0.074^{***} (0.021)	0.083^{***} (0.026)
Kleibergen-Paap LM p-value (Under-id)	0.028	0.034	0.212	0.197	0.492
Kleibergen-Paap Wald F statistic (Weak inst)	9.05	8.26	2.71	5.38	4.41

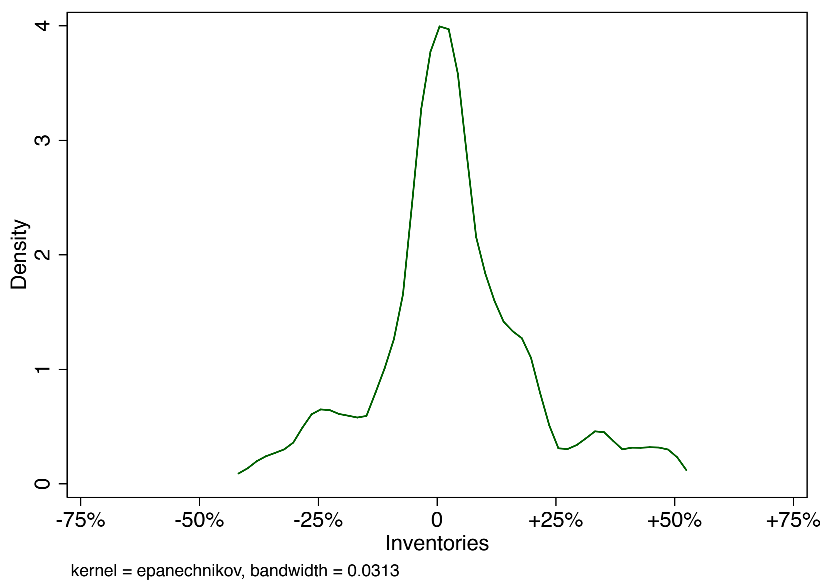
Notes: One observation is a plant in a particular month. *High Quality share of production* is the share of a plant's total production during a fishing season that is reported as high quality "prime" output. *Share of inputs from VI suppliers* is the share of a plant's inputs that come from VI suppliers during a season. *Has high technology* is a dummy variable equal to one if the plant in question has any steam drying technologies installed. Column 1 instruments for *Share of inputs from VI suppliers* with the number of independent boats present in the port at the end of the previous month. To construct this measure, each boat is assigned to the port of its last delivery in month $t-1$. In the first month of the season, boats are assigned to the port of their first delivery. Column 2 instruments for *Share of inputs from VI suppliers* with the number of wooden boats present in the port at the end of the previous month. Column 3 instruments for *Share of inputs from VI suppliers* with the mean, median, 1st and 5th quintiles and standard deviation of monthly port level windspeed. Column 4 instruments for *Share of inputs from VI suppliers* with the mean, median, 1st and 5th quintiles and standard deviation of monthly port level cloudiness. Column 5 instruments for *Share of inputs from VI suppliers* with the mean, median, 1st and 5th quintiles and standard deviation of monthly port level windspeed and cloudiness. Standard errors are clustered at the port level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

FIGURE A1: AVERAGE OUTPUT QUALITY AND FIRM SIZE



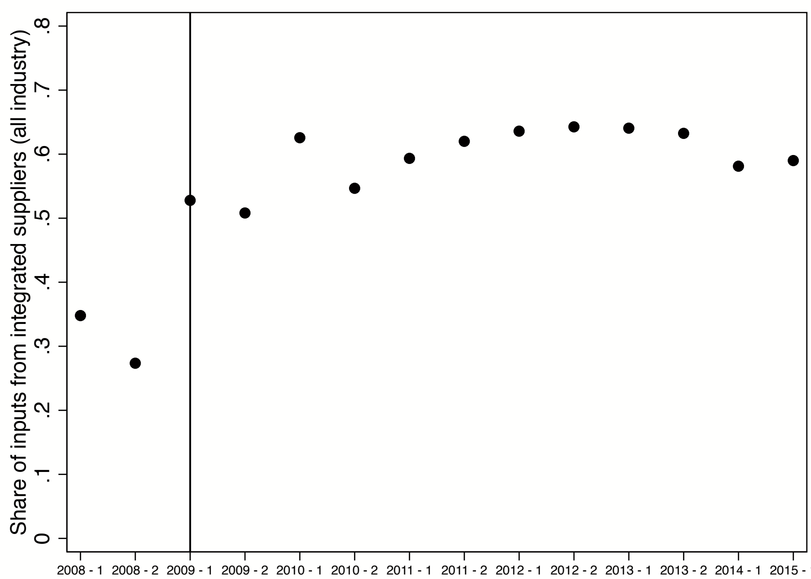
Notes: Each dot represents one fishmeal firm in our sample. Total production is the total weight of fishmeal the firm produced during our data period and average protein content is the quantity weighted average protein content of the firm's fishmeal exports.

FIGURE A2: DENSITY OF INVENTORIES



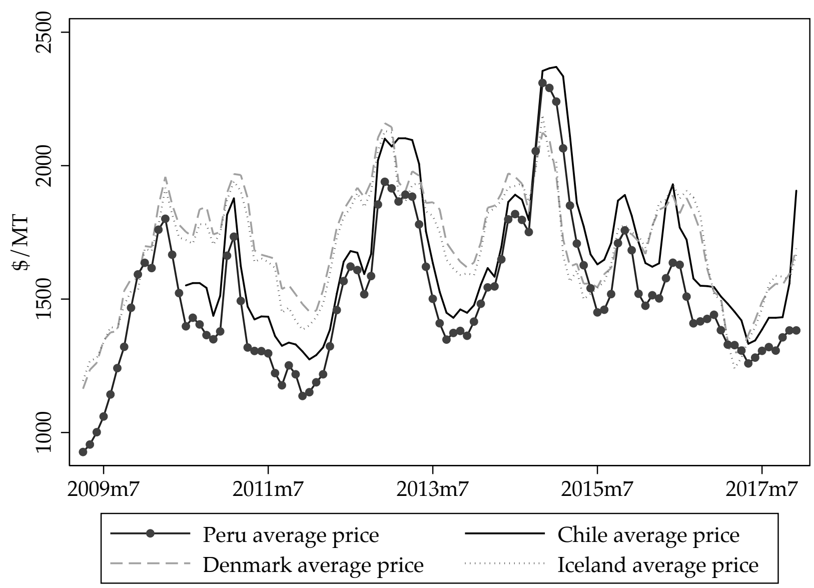
Notes: Kernel density of estimated inventories. Inventories are defined as the ratio of (Total Production - Total Exports) to Total Production, where Total Production is a firm's production during a given production season and Total Exports are the sum of exports that are shipped during the production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

FIGURE A3: 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.

FIGURE A4: FISHMEAL PRICES IN PERU AND OTHER COUNTRIES

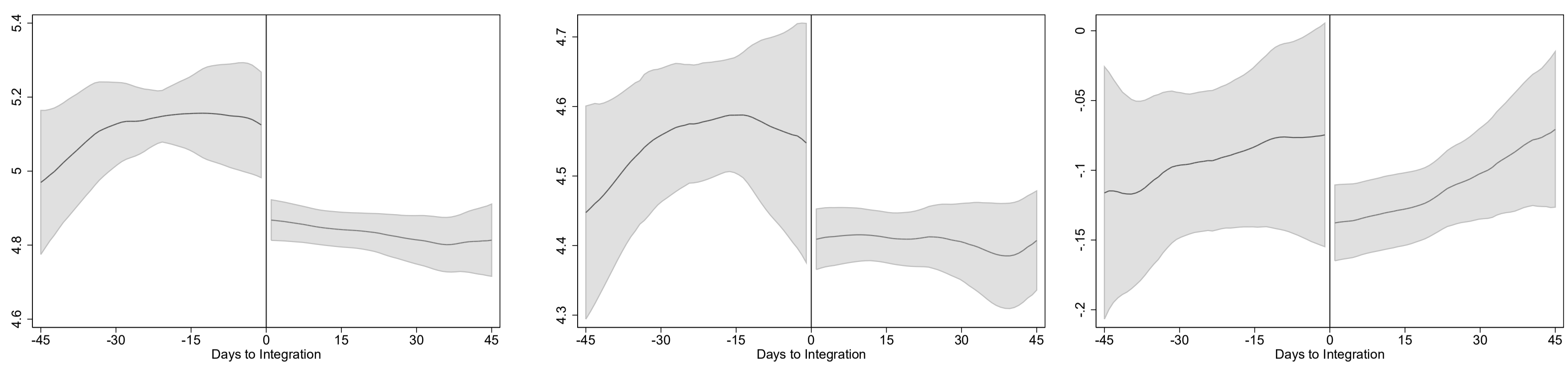


Notes: This figure shows the evolution of the average fishmeal price in other fishmeal exporting countries. Denmark and Iceland export mostly "Super Prime" fishmeal grade while Peru exports mostly "Prime" grade fishmeal.

FIGURE A5: EVENT STUDIES OF BOAT BEHAVIOR

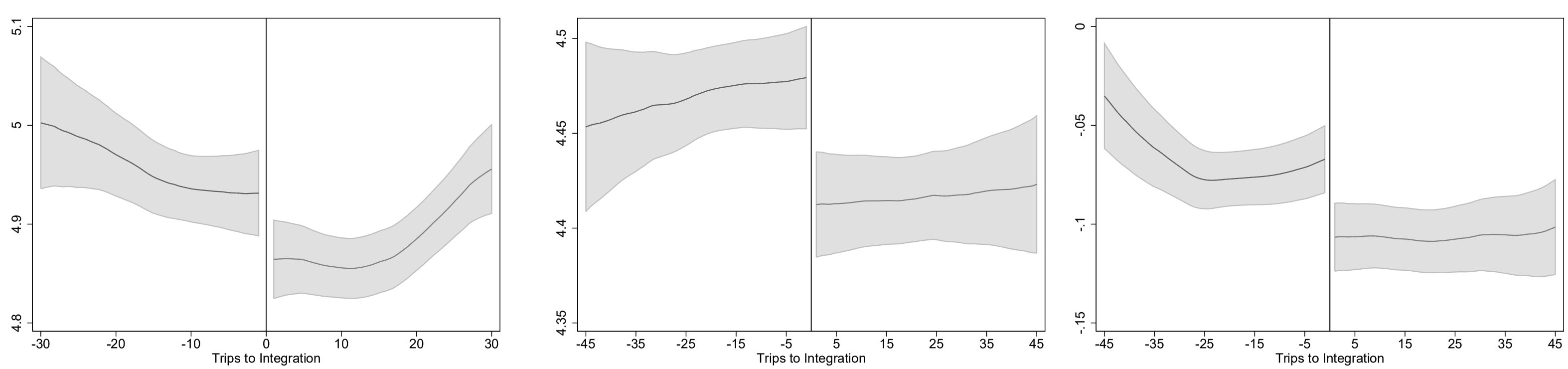
PANEL A: 45 DAYS BEFORE AND AFTER INTEGRATION

a Log(Quantity Supplied) b Log(Max. Distance From Port) c Log(Total Time Spent at Sea)



PANEL B: 45 TRIPS BEFORE AND AFTER INTEGRATION

d Log(Quantity Supplied) e Log(Max. Distance From Port) f Log(Total Time Spent at Sea)



Notes: Lines show local linear fits with 95 percent confidence intervals in gray. One observation is a boat during a fishing trip. *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. We include only observations from boat×plant pairs which were at initially not integrated and later became integrated. In panel A we include any observations in the 45 days before and after integration. In panel B we include the 45 trips before and after integration for each boat×plant pair if available.

Appendix B Details of Decomposition Shown in Table 2

This appendix describes the variance decomposition performed in Table 2 in detail. The goal of the decomposition is to attribute realized changes in the share of inputs firms receive from vertically integrated suppliers (Share VI) to three relevant margins of adjustment. These margins are:

(1) The *VI intensive margin*: firms may increase *Share VI* by increasing the share of inputs they receive from integrated suppliers holding the quantity of those suppliers constant. As integrated suppliers deliver some of their catch to non-owner firms (see Figure 1 for more detail) a firm may direct integrated suppliers to deliver a larger fraction of their quota to the owner firm.

(2) The *VI extensive margin*: firms may increase *Share VI* by purchasing new suppliers while holding the share of inputs they source from each integrated supplier constant.

(3) The *Independent Margin*: firms may increase *Share VI* by purchasing less from independent boats, holding all else constant.

To aid in our decomposition, we next define a series of useful variables:

Definition of variables

- $Total_t$ is the total quantity of inputs bought by all firms in the industry during season t.
- $VI_{i,t}$ is the total quantity of inputs sourced from VI suppliers by firm i during season t.
- $Total\ VI_{i,t}$ is the total quantity of inputs produced by the suppliers owned by firm i during season t. Some boats owned by firm i may deliver their inputs to another firm so, by definition, $\text{VI}_{i,t} \leq \text{Total VI}_{i,t}$. Total $\text{VI}_{i,t}$ is determined by the total quota allocated to each VI supplier as boats typically fish their entire quotas on a given season.
- $Indep_{i,t}$ is the total quantity of inputs sourced from independent suppliers by firm i during season t (suppliers not integrated with downstream firm i in season t).
- $Share\ VI_{i,t}$ is the share of inputs sourced from VI suppliers in season t for firm i. Note that

$$\text{Share VI}_{i,t} = \frac{\text{VI}_{i,t}}{\text{VI}_{i,t} + \text{Indep}_{i,t}}.$$

Decomposing changes in Share VI

We now show how the change in *Share VI* for firm i between season $t-1$ and t can be decomposed into these three margins:

$$\begin{aligned}
\text{Share VI}_{i,t} - \text{Share VI}_{i,t-1} &= \frac{\text{VI}_{i,t}}{\text{VI}_{i,t} + \text{Indep}_{i,t}} - \frac{\text{VI}_{i,t-1}}{\text{VI}_{i,t-1} + \text{Indep}_{i,t-1}} \\
&= \frac{\frac{\text{VI}_{i,t}}{\text{Total}_t}}{\frac{\text{VI}_{i,t}}{\text{Total}_t} + \frac{\text{Indep}_{i,t}}{\text{Total}_t}} - \frac{\frac{\text{VI}_{i,t-1}}{\text{Total}_{t-1}}}{\frac{\text{VI}_{i,t-1}}{\text{Total}_{t-1}} + \frac{\text{Indep}_{i,t-1}}{\text{Total}_{t-1}}}
\end{aligned}$$

$$= \underbrace{\frac{\frac{\text{VI}_{i,t}}{\text{Total VI}_{i,t}}\frac{\text{Total VI}_{i,t}}{\text{Total}_t}}{\frac{\text{VI}_{i,t}}{\text{Total VI}_{i,t}}\frac{\text{Total VI}_{i,t}}{\text{Total}_t}+\frac{\text{Indep}_{i,t}}{\text{Total}_t}} - \frac{\frac{\text{VI}_{i,t-1}}{\text{Total VI}_{i,t-1}}\frac{\text{Total VI}_{i,t}}{\text{Total}_t}}{\frac{\text{VI}_{i,t-1}}{\text{Total VI}_{i,t-1}}\frac{\text{Total VI}_{i,t}}{\text{Total}_t}+\frac{\text{Indep}_{i,t}}{\text{Total}_t}}}_{\text{VI Intensive (Intensity of own use of VI suppliers inputs)}} +$$

$$\underbrace{\frac{\frac{\text{VI}_{i,t-1}}{\text{Total VI}_{i,t-1}}\frac{\text{Total VI}_{i,t}}{\text{Total}_t}}{\frac{\text{VI}_{i,t-1}}{\text{Total VI}_{i,t-1}}\frac{\text{Total VI}_{i,t}}{\text{Total}_t}+\frac{\text{Indep}_{i,t}}{\text{Total}_t}} - \frac{\frac{\text{VI}_{i,t-1}}{\text{Total VI}_{i,t-1}}\frac{\text{Total VI}_{i,t-1}}{\text{Total}_{t-1}}}{\frac{\text{VI}_{i,t-1}}{\text{Total VI}_{i,t-1}}\frac{\text{Total VI}_{i,t-1}}{\text{Total}_{t-1}}+\frac{\text{Indep}_{i,t}}{\text{Total}_t}}}_{\text{VI Extensive (Integration - boat purchases or sales)}} +$$

$$\underbrace{\frac{\frac{\text{VI}_{i,t-1}}{\text{Total}_{t-1}}}{\frac{\text{VI}_{i,t-1}}{\text{Total}_{t-1}}+\frac{\text{Indep}_{i,t}}{\text{Total}_t}} - \frac{\frac{\text{VI}_{i,t-1}}{\text{Total}_{t-1}}}{\frac{\text{VI}_{i,t-1}}{\text{Total}_{t-1}}+\frac{\text{Indep}_{i,t-1}}{\text{Total}_{t-1}}}}_{\text{Indep margin (Buying more/less from independent suppliers)}}$$

Variance decomposition

With this equation in hand, we can then decompose the within firm variation in firm sales using a procedure commonly used in the trade literature. Specifically, the variance decomposition presented in Table 2 is conducted by conducting regressions each of the the three components in the equation above on Share $\text{VI}_{i,t}$ − Share $\text{VI}_{i,t-1}$ controlling for firm fixed effects. The results are available in Table B1 below. The coefficients for the three regressions sum up to one and so each coefficient is the contribution of the corresponding margin to the variance of the right-had side variable.

Using the decomposition to quantify the impact of each margin in Table 4

While the variation in changes in *Share VI* as a whole can be decomposed into to the three margins above in the proportions presented in Table 2, the changes in the quality premium displayed in Table 4 may reflect adjustments along these margins in ways that differ from average. That is, firms may rely particularly on certain margins of adjustment when responding to the quality premium. To see if this is the case, we repeat the analysis shown in columns 5 and 7 of Table 4—a main result of the paper—but replace the dependent variable with each of the three terms defined in the equation above. As for the variation decomposition, the coefficients for each margin sum up to the corresponding coefficients in in column 5 (for OLS) and 7 (for IV) of Table 4. The *VI extensive margin* is by far the largest contributor to our observed effect, that is, much of the effect is driven by firms acquiring more boats when the quality premium is high. The second largest contributor is the *VI intensive margin*, suggesting that firms also shift towards the suppliers they already own when the premium is high. Interestingly, the coefficient on the independent margin is negative and insignificant, suggesting that this margin plays little role in our observed effect.

TABLE B1: VARIANCE DECOMPOSITION OF CHANGES IN SHARE VI

Dep. var:	VI extensive margin (Boats purchases or sales)	VI intensive margin (Intensity of own use of VI suppliers)	Indep. margin (Buying less/more from Indep.)
	(1)	(2)	(3)
Share $\text{VI}_{i,t}$ − Share $\text{VI}_{i,t-1}$	0.350^{***}	0.156^{***}	0.495^{***}
	(0.037)	(0.038)	(0.048)
Firm FEs	Yes	Yes	Yes

Notes: One observation is a firm during a production season. The *VI extensive margin* corresponds to the change in the variable due to the firm buying or selling boats. The *VI intensive margin* corresponds to changes in the own use share of all the inputs produced by VI suppliers. VI suppliers sometimes supply other firms (around 10% of the time - see Figure 1) so a firm could decide to take in more or less of its VI suppliers inputs. The last contribution is the *Indep. margin* which corresponds to the firm buying more or less from independent boats than in the previous season which mechanically impacts the share of inputs from VI suppliers. The beginning of this Appendix B provides the computational details of the decomposition. Standard errors are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE B2: QUANTIFYING THE IMPACT OF EACH MARGIN IN TABLE 4

	OLS			IV		
Dep. var:	VI Extensive margin	VI Intensive margin	Indep. margin	VI Extensive margin	VI Intensive margin	Indep. margin
	(1)	(2)	(3)	(4)	(5)	(6)
Upgradable share of production (t-1) × Quality premium	2.582^{***}	0.328^{***}	-0.201	2.674^{***}	0.401^{***}	-0.539
	(0.613)	(0.084)	(0.392)	(0.542)	(0.137)	(0.333)
Upgradable share of production (t-1)	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.	0.00	-0.00	0.00	0.00	-0.00	0.00
N	191	191	191	191	191	191
R^2	0.38	0.17	0.09	0.38	0.17	0.09

Notes: One observation is a firm during a production season. This Table replicates exactly the regressions in Table 4 where the dependent variable is replaced by each of the margin presented above. The OLS specific is the same as column 5 of 4 while the IV is similar to column 7. The *VI extensive margin* corresponds to the change in the variable due to the firm buying or selling boats. The *VI intensive margin* corresponds to changes in the own use share of all the inputs produced by VI suppliers. VI suppliers sometimes supply other firms (around 10% of the time - see Figure 1) so a firm could decide to take in more or less of its VI suppliers inputs. The last contribution is the *Indep. margin* which corresponds to the firm buying more or less from independent boats than in the previous season which mechanically impacts the share of inputs from VI suppliers. The beginning of this Appendix B provides the computational details of the decomposition. Standard errors clustered at the firm level are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Appendix C Dynamic Theoretical Framework and Relational Contracts

Dynamic theoretical framework

The model presented in the main body of the paper assumes that all transactions are done on the spot market. This stylized version of the model results in the upstream party not taking any action when integrated and the absence of incentives to take a quality-increasing action ($a_2 = 0$). In this version of the model, we follow closely Baker *et al.* (2001, 2002) in allowing the downstream party to use relational contracts to incentivize the quality action.

We make the same assumptions for Q as before, but add a shock to the alternative use P:

$$P = a_1 + \epsilon$$
$$Q = Q_0 - \gamma a_1 + \delta a_2$$

where ϵ is orthogonal to any action taken by the upstream party[48]. We assume that $\epsilon = \bar{\epsilon}$ with probability $\frac{1}{2}$ and $\epsilon = -\bar{\epsilon}$ with probability $\frac{1}{2}$ and that ϵ is known by the upstream party at the time of delivery of the inputs. [49]

As in the main text model, we assume that both P and Q are not contractible. P -the quantity focused alternative use- is perfectly observable at the time of delivery of the inputs, but Q -the quality surplus- is only observed to the downstream party with some delay (e.g. once the inputs are processed).[50] To incentivize the quality-increasing action, the downstream party can offer a payment contingent on the realization of the surplus Q to the upstream party. However, since this payment can only be made after the inputs are delivered, the downstream party can only credibly promise to make this delayed payment through repeated interactions with the upstream party.[51] Note again that at the time of delivery of the inputs, since all parties know the value of Q_0, and because $P = a_1 + \epsilon$ is observable, Q has an observable portion (in expectation) at the time of delivery of the inputs: $\tilde{Q} = Q_0 - \gamma \mathbb{E}(a_1|P) = Q_0 - \gamma P$. Hence, a payment on the spot, proportional to $\tilde{Q}$ is still feasible.

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)

[48] We could also assume uncertainty over the realization of the Q surplus, but it would not change the intuition of the result below.

[49] As in the main text model, we assume that $0 \leq \delta \leq 1$ and $0 \leq \gamma \leq 1 - \alpha$. Also, note again that P could itself be the result of a bargaining process between the boat and a quantity focused firm.

[50] In our context, fish quality can hardly be assessed when the fish is offloaded at the factory. However, once the fish is processed in the factory, fishmeal quality can be measured.

[51] In the model, we suppose that this delay is shorter than a full time period, so the surplus Q is observed before the next period starts and the next transaction occurs. Thus, the downstream party does not discount the payment.

We write the relational compensation contract as $\{b(Q)\}$, where $b(Q)$ is a payment contingent on the observation of Q[52].

First Best

The first-best actions $\{a_1^*, a_2^*\}$ maximize the expected value of Q minus the cost of actions $c(a_1, a_2) = \frac{1}{2}a_1^2 + \frac{1}{2}a_2^2$. This gives $a_1^* = 0$ and $a_2^* = \delta$ and total surplus:

$$S^* = Q(a_1^*, a_2^*) - c(a_1^*, a_2^*) = Q_0 + \frac{1}{2}\delta^2$$

Spot Market

On the Spot Market, the supplier does not take the first best actions. In particular, under both Spot Employment and Spot Outsourcing $a_2 = 0$, because the downstream firm cannot credibly commit to rewarding the supplier's quality-focused actions.

Relational Contracts

Whether the upstream party is integrated with the downstream party or not, if she accepts the relational contract, she will choose actions a_1 and a_2 to solve:

$$\max_{a_1, a_2} = b\big(Q(a_1, a_2)\big) - c(a_1, a_2)$$

It is straightforward to see that the first best can only be achieved if the contract is of the form $b\big(Q(a_1, a_2)\big) = Q(a_1, a_2) - t$, where t is a transfer independant of the surplus Q. In the remainder of this section, we assume that the relational contract is written in such a way and that under relational employment (when the downstream party owns the supplier) or under relational outsourcing (when the supplier is independent), the suppliers take the first best actions $\{a_1^*, a_2^*\}$ [53].

This relational contract is self-enforcing if both parties choose to honor it for all possible realizations of P. We next explore the feasibility of the first best contract under employment and outsourcing and show that if the shock to the alternative use P is high enough, the first best contract is only self-enforceable under Relational Employment. We use superscripts $\{RE, SE, RO, SO\}$ to indicate Relational Employment, Spot Employment, Relational Outsourcing and Spot Outsourcing and $\{U, D, S\}$ to denote the upstream party, downstream party and overall surplus respectively.

Relational Employment

Since $S^{SE} > S^{SO}$, [54] if one of the two party reneges, the downstream party will retain ownership and earn D^{SE} in perpetuity, while the upstream party will earn U^{SE} in perpetuity. The upstream party reneges if

[52] Alternatively, we could consider a more general relational compensation contract of the form $\{s, b(Q)\}$ as in Baker *et al.* (2002), where salary s is paid by downstream to upstream at the beginning of each period and $b(Q)$ is a payment contingent on the realization of Q. Such an assumption would not change our results below.

[53] In particular, t must be such that $t \leq Q(a_1^*, a_2^*) - c(a_1^*, a_2^*) = Q_0 + \frac{1}{2}\delta^2$ so that the downstream party would accept the contract

[54] See the proof in the main text model.

she refuses to accept the promised payment $b(Q)$. Thus, the upstream party does not renege as long as:

$$b(Q) + \frac{1}{r}U^{RE} \geq \frac{1}{r}U^{SE} \tag{7}$$

Similary, the downstream party reneges if she takes the inputs and refuses to pay the bonus to the upstream party. The downstream party honors the contract as long as:

$$\frac{1}{r}D^{RE} \geq b(Q) + \frac{1}{r}D^{SE} \tag{8}$$

Summing (7) and (8), and noting that $S^X = U^X + D^X$, we get the following necessary condition:

$$S^{RE} \geq S^{SE} \tag{9}$$

(9) is actually sufficient as well as necessary, because a transfer t can always be chosen so that when (9) is statisfied, (7) and (8) are also satisfied [55].

As $S^{RE} = S^* = Q_0 + \frac{1}{2}\delta^2$ and $S^{SE} = S^* = Q_0$, (9) is satisfied, and so **the first best can always be enforced under Relational Employment**.

Relational Outsourcing

Since $S^{SE} > S^{SO}$, if one of the two party reneges, the upstream party will purchase the ownership right from the downstream party for some price π, after which the upstream and downstream parties will earn U^{SE} and D^{SE}, respectively, in perpetuity. If the upstream party reneges on the relational-outsourcing contract, she negotiates to sell the good for the spot-outsourcing price of $(1-\alpha)P + \alpha\tilde{Q}$, where α is the supplier's bargaining coefficient and $\tilde{Q}$ is the observable portion of the surplus Q as in the main text model. Thus, the upstream party honors the contract as long as:

$$b(Q) + \frac{1}{r}U^{RO} \geq (1-\alpha)P + \alpha\tilde{Q} + \frac{1}{r}U^{SE} + \pi \tag{10}$$

The timing of reneging is slightly different for the downstream party. She has no incentives to renege at the time of delivery of the inputs as Q is unobservable. Instead, the downstream party reneges if she takes the inputs and refuses to pay the bonus to the upstream party. The downstream party does not renege as long as:

$$\frac{1}{r}D^{RO} \geq b(Q) + \frac{1}{r}D^{SE} - \pi \tag{11}$$

If (10) holds for all P and $\tilde{Q}$, then it must hold for the maximum value of $(1-\alpha)P + \alpha\tilde{Q}$. Summing (10) and (11) we get the following necessary condition:

$$\frac{1}{r}S^{RO} \geq \frac{1}{r}S^{SE} + \max\{(1-\alpha)P + \alpha\tilde{Q}\} \tag{12}$$

Evaluated at $\{a_1^*, a_2^*\}$, (12) is equivalent to:

[55] For both (7) and (8) to be satisfied and the supplier to accept the contract, it must be that $Q_0 + \frac{1}{2}\frac{r}{1+r}\delta^2 \leq t \leq Q_0 + \frac{1}{2}\delta^2$

$$(1 - \alpha\gamma - \alpha)\bar{\epsilon} \leq \frac{1}{2r}\delta^2 - \alpha Q_0 \tag{13}$$

Thus, if $\bar{\epsilon}$ is high enough, **the first best contract cannot be enforced under Relational Outsourcing**.

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. As a result, when the value of the input is high in its alternative use (e.g. if the supplier happens to get more fish or if there is less competition on a specific day in the quantity-focused sector), quality-oriented firms may be unable to prevent the suppliers they interact with from breaking their relationship and selling the goods for its alternative use. In contrast, under Relational Employment, the downstream firm has control over the inputs, and will choose to allocate them efficiently regardless of the value of the inputs in their alternative use.

A key testable prediction of this model in our context is that (1) independent suppliers under a relational contract should not adopt a behavior consistent with delivering higher quality inputs and (2) downstream firms should not produce higher quality output when they source more of their inputs from non-integrated suppliers with whom they have a relational contract.

Empirical evidence on relational contracts in the Peruvian fishmeal industry

We now test these predictions. We show results for two different, frequency-of-interacting based observable proxies for a supplier being engaged in a relational outsourcing contract with a downstream firm: specifically, (i) that the supplier delivers more than 80 percent of its fish to the same fishmeal firm (approx. 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 (approx. the 25th percentile of the underlying distribution) in a given production season and does so for three seasons in a row. We "turn on" the inferred contract at the start of the relevant period, not when the "cut-off" used in the proxy is reached.

In Appendix Table C1, which is analogous to Table 5, we show that relational outsourcing contracts appear not to be used to incentivize supplier quality-increasing actions in the Peruvian fishmeal industry, consistent with the dynamic version of our theoretical framework above. 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.

In Appendix Table C2, which is analogous to Table 6, 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. These results indicate that repeated interactions are not used to incentivize the delivery of high quality inputs in the Peruvian fishmeal sector, as the model above predicts.

In combination with the results in the body of the paper, the findings in tables 5 and 6 provide support for the idea that vertical integration enables downstream firms to incentivize specific supplier behaviors—and consequently the types of output associated with those behaviors—that other organizational structures do not.

Organizational structure and supplier behavioral response to plant input quality needs

The dynamic model with relational contracts presented above also predicts the following result. When the return on the quality surplus Q of the quality-increasing action is higher (when δ increases), integrated suppliers will choose a higher level of that action ($a_2^* = \delta$ increases). We test this prediction below.

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 in Section 6, 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, but now differentially when the downstream plant produces low or high quality output.

We first estimate the following equation:

$$\begin{aligned}\mathrm{B}_{ijt} = \alpha &+ \beta_1 \text{ I[VI} \times \text{supplies owner firm]}_{ijt} \times \text{I[Low Quality]}_{jt} \\ &+ \beta_2 \text{ I[VI} \times \text{supplies owner firm]}_{ijt} \times \text{I[High Quality]}_{jt} \\ &+ \gamma_{ij} \times \text{I[High Quality]}_{jt} + \gamma_{ij} \times \text{I[Low Quality]}_{jt} + \delta_t + \varepsilon_{ijt}\end{aligned} \tag{14}$$

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 $\text{I[High Quality]}_{jt}$).[56] We include Supplier $\times$ Plant $\times$ 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 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.

The results in Appendix Table C3 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.[57] 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. Overall, the evidence confirms the prediction from the relational model that integrated suppliers will provide more of the quality focused action when its return to the quality surplus is higher.

[56] 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.

[57] The estimated decrease in quantity per trip when integrating with the plant being supplied is bigger when the plant is producing low quality fishmeal. This is surprising in light of our results in sections 7 and 5. A possible explanation is that independent suppliers face strong incentives to deliver high input quantities when the plant being supplied is attempting to produce high output quantities (and prioritizing output quality less) and that integrated suppliers do not.

TABLE C1: 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
	(0.007)	(0.009)	(0.006)
Date FEs	Yes	Yes	Yes
Supplier × Plant FEs	Yes	Yes	Yes
N	319,827	140,365	163,165
N distinct suppliers	1,149	1,081	1,081
R^2	0.62	0.42	0.34

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
	(0.020)	(0.022)	(0.015)
Date FEs	Yes	Yes	Yes
Supplier × Plant FEs	Yes	Yes	Yes
N	319,827	140,365	163,165
N distinct suppliers	1,149	1,081	1,081
R^2	0.62	0.42	0.34

Notes: For panel A and B, one observation is a boat during a fishing trip. For panel C, one observation is a boat during a fishing season. *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. The number of observations varies across columns as GPS variables for a given trip are sometimes missing. We define I[Relational ×supplies relational firm] to be equal to one if the supplier is (i) currently under a relational contract (ii) currently delivering to the firm it is under a relational contract with. 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 two 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 three consecutive fishing seasons. For both definitions, wooden and steel boats can be in a relational contract. (Only allowing steel boats to be under a relational contract does not change the magnitude nor significance of these results). Because we include Boat × Plant FEs, I[Relational ×supplies relational firm] is identified from boats moving in and out of a relational contract. Standard errors clustered at the boat level are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE C2: OUTPUT QUALITY AND SHARE OF INPUTS FROM VERTICALLY INTEGRATED SUPPLIERS AND SUPPLIERS UNDER A RELATIONAL OUTSOURCING CONTRACT

Panel A: Relational outsourcing = 80% of offloads to the same firm for 2 consecutive production seasons

Dep. var:	High Quality share of prod.		Protein content	
	(1)	(2)	(3)	(4)
Share of inputs from VI suppliers	0.278^{**}	0.285^{**}	1.089^{***}	1.120^{***}
	(0.114)	(0.119)	(0.376)	(0.369)
Share of inputs from relational suppliers	-0.084	0.004	-0.260	-0.127
	(0.079)	(0.060)	(0.515)	(0.429)
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.	0.75	0.75	65.7	65.7
N	275	275	208	208
R^2	0.76	0.81	0.79	0.80

Panel B: Relational Outsourcing = more than 10 interactions with the same firm for at least 3 consecutive production seasons

Dep. var:	High Quality share of prod.		Protein content	
	(1)	(2)	(3)	(4)
Share of inputs from VI suppliers	0.316^{**}	0.289^{**}	1.145^{***}	1.134^{***}
	(0.119)	(0.113)	(0.262)	(0.268)
Share of inputs from relational suppliers	-0.381^{***}	-0.427^{***}	0.373	0.608
	(0.131)	(0.144)	(1.833)	(1.699)
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.	0.75	0.75	65.7	65.7
N	275	275	208	208
R^2	0.76	0.82	0.79	0.80

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 inputs that come from VI suppliers during a season. *Share of inputs from relational suppliers* is the share of a firm's inputs that come from VI suppliers 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 two 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, for at least three consecutive fishing seasons. For both definitions, wooden and steel boats can be in a relational contract. (Only allowing steel boats to be under a relational contract does not change the magnitude nor significance of these results). *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 C3: SUPPLIER BEHAVIOR, VERTICAL INTEGRATION AND OUTPUT QUALITY

	Panel A		
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^{***} (0.043)	0.019 (0.046)	-0.013 (0.031)
I[VI × supplies owner firm] × I[Plant producing high quality]	-0.066^{**} (0.029)	-0.065^{**} (0.026)	-0.042^{**} (0.019)
Date FEs	Yes	Yes	Yes
Supplier × Plant × High Quality FEs FEs	Yes	Yes	Yes
N	319,827	140,365	163,165
N distinct suppliers	1,149	1,081	1,081
R^2	0.62	0.44	0.35
Two coefficients equal (p-val)	0.0012	0.028	0.089

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 level are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Appendix D How Demand for Output Quality Affects Vertical Integration

In this section, we develop an alternative strategy to the one presented in section 5 to show that firms choose to integrate their suppliers when they face increased demand for high quality fishmeal. To do so, we develop an IV strategy that exploits quality-differentiated firm-specific demand shocks. We find that these shocks cause firms to increase their Share VI.

D.1 Empirical strategy

The logic behind our instruments for the quality grade of a firm's exports at a given point in time relies on two important facts about the Peruvian fishmeal sector. First, there is an exceptionally tight link between quality grade and export destination. 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.[58] Sales records provided by a large firm drive home this connection. Country names are frequently used as a shorthand to represent different qualities—the quality column for exports is often simply filled in with the name of a 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 integrate or sell suppliers in a given production season in response to high or low demand from particular importer countries.

In the second stage, we estimate how acquisitions/sales of suppliers and firms' input mix respond to the quality grade produced:

$$\mathrm{VI}_{it} = \alpha + \beta_1 \mathrm{Quality}_{it} + \gamma_i + \delta_t + \varepsilon_{it} \tag{15}$$

We control for firm and production season fixed effects and cluster the standard errors at firm level as in Section 7.

To construct our demand shocks, we follow an approach similar to Bastos *et al.* (2018) (see also Park *et al.* (2010); Brambilla *et al.* (2012)). In the first stage, quality grade produced is instrumented by demand shocks from specific destinations as follows:

$$\mathrm{Quality}_{it} = \gamma_i + \delta_t + \sum_j \beta_j \left(\mathrm{I}^j_{i,\bar{t}} \, S^j_{-i,t}\right) + \varepsilon_{it} \tag{16}$$

where j is an export destination country, and $\mathrm{I}^j_{i,\bar{t}} \, S^j_{-i,t}$ are our excluded instruments. $\mathrm{I}^j_{i,\bar{t}}$ is a dummy variable equal to one if firm i exports to destination j at least once during our analysis period. $S^j_{-i,t}$ is the leave-firm-out share of Peru's fishmeal exports going to country j in season t, a proxy for the relative demand for firm i 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 $S^j_{-i,t}$ and $\mathrm{I}^j_{i,\bar{t}}$. A high β_j should represent a high quality importer country. We present the results of this specification in columns 3 and 4 of Appendix Table D1).

[58] See Appendix Table A1 for a list of the main importers of Peruvian fishmeal and the average quality imported. Note that, as for humans, quantity and quality of feed (the latter here defined by protein content) are highly imperfect substitutes for the animals that consume fishmeal.

In an alternative approach (presented in columns 5 and 5 of Appendix Table D1), we replace $S^{j}_{-i,t}$ by $Quality^{j}_{-i,t}$, the leave-firm-out average quality of Peru's fishmeal exports going to country j in season t. In that case, a positive and high β_j represents a high willingness of Peruvian firms to respond to the higher demand for quality expressed by other countries. Conversely, a negative β_j represents a substitution effect: if an importer country starts buying higher quality output from other exporters, that same country would start buying low quality from other firms.

D.2 Results

We find that firms respond to positive shocks to demand for high quality fishmeal by sourcing a higher share of their inputs from suppliers that have been integrated.[59]

The OLS and the second stage IV results are reported in Appendix Table D1. The estimates indicate that a one percentage point increase in the average protein content demanded—about 20 percent of approx. 63-68 percent range observed in Peru—induces the firm to source between 4 and 6 percent more of its inputs from integrated suppliers. As presented in Table 2, most of the variation in the share of inputs sourced from integrated suppliers comes from acquiring and selling suppliers.

Our interpretation of the results in Appendix Table D1 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 (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 relative 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. 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). Since China represents about 50 percent of total exports, we split China into 4 sub-countries, and we do so by using the destination port within China of each specific shipment. Our results are very similar if instead we use the 10 biggest importer countries or we use LASSO regressions to choose the importer countries whose demand fluctuations most affect quality grade exported.[60] The first stage results are reported in Appendix Table D1 [61].

Since the existing literature that uses destination country demand shocks for identification often struggles with weak instruments, we compute the Kleibergen-Paap test statistics. Comparing the statistics reported in Table 4 to the Stock-Yogo critical values[62], while we do not pass the Kleibergen-Paap underidentification test, we reject the null hypothesis that our instruments are weak (as the F-statistic surpasses the 10 percent critical value). We also reject the hypothesis that the coefficients on the excluded instruments

[59] The IV coefficients in columns 3 to 6 are bigger than the OLS coefficients in columns 1 and 2. We believe this is in part to be expected because the relationship between output quality and vertical integration *at firm level* estimated in Table 3 partly reflects a causal effect of organizational structure on output quality and partly other mechanisms. If the OLS estimates in that table are biased upwards, we would expect the OLS estimates here to be biased downwards, as we study the inverse relationship.

[60] LASSO (least absolute shrinkage and selection operator) is a regression analysis method that performs both variable selection and 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 eight importer countries.

[61] The sign of the coefficients for each instrument in column 3 and 4 are broadly consistent with the relative average quality imported by each country (See Appendix Table A1). It is more difficult to interpret the sign of the first stage in column 5 and 6 as the sign reflects the strength of the tie between a specific destinations and Peruvian exporters.

[62] 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.

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 additionally 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.* (2018) 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 are consistent with the integration→quality relationship shown in Section 7 and confirm the results shown in section 5 that firms integrate when they face incentives to quality upgrade. We conclude that Peruvian manufacturing firms are aware of, and act on, their greater ability to produce high quality grade output when their suppliers have been integrated.

Table D1: Vertically Integrated Share of Inputs and Output Quality - Instrumenting with Firm-specific Demand Shocks

Dep. var:	Share of inputs from VI suppliers					
	OLS	OLS	IV	IV	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)
Protein content	0.036***	0.037***	0.078*	0.079*	0.055**	0.057**
	(0.012)	(0.011)	(0.043)	(0.042)	(0.026)	(0.027)
Log(Sales)		−0.004		−0.028		−0.016
		(0.013)		(0.025)		(0.018)
Season FEs	Yes	Yes	Yes	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes	Yes	Yes	Yes
Mean of Dep. Var.	0.45	0.45	0.45	0.45	0.45	0.45
N	192	192	192	192	192	192
R^2	0.92	0.92	0.92	0.92	0.92	0.92
	First Stage					
Dep. var:	Protein Content					
	(1)	(2)	(3)	(4)	(5)	(6)
China - HUANGPU			−2.029	−1.152	−5.563***	−5.125***
China - SHANGHAI			0.380	0.801	−1.705**	−1.843**
Germany			−0.219***	−0.214***	−0.037***	−0.040***
China - other			−1.791**	−1.922***	−0.406	−0.155
Japan			−0.175	−0.454	−0.166	−0.207
China - DALIAN			−0.168	0.298	0.024	0.008
Chile			0.392***	0.405***	0.078***	0.078***
Vietnam			0.124	0.111	0.321***	0.253**
Turkey			−0.004	−0.016	−0.001	−0.002
Indonesia			0.435*	0.357*	0.191	0.101
Spain			0.310*	0.295	−0.064	−0.014
Australia			0.048	0.056*	0.002	0.000
Canada			−0.135	−0.239	0.015	0.012
France			−0.600*	−0.498*	−0.232	−0.145*
Greece			0.000	−0.001	0.002	0.001
Italy			−0.007	−0.003	0.004	0.004
Bulgaria			0.020	0.015	0.001	0.001
Kleibergen-Paap LM p-value (under-id)			0.53	0.46	0.53	0.45
Kleibergen-Paap Wald F statistic (weak inst)			625.5	598.6	1141.9	797.7

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 at least one export in our analysis period to each of the top 20 destination countries with leave-firm-out share of Peru's fishmeal exports towards the destination in the relevant season (columns 3 and 4) or leave-firm-out average protein content exported towards the destinatiion in the relevant season (columns 5 and 6). Standard errors clustered at the firm level are included in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.