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VERTICAL INTEGRATION, SUPPLIER BEHAVIOR, AND QUALITY UPGRADING  
AMONG EXPORTERS

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### **ABSTRACT**

We study the relationship between firms' output quality and their choice of organizational structure. To do so, we use data on each step of the production and transaction chain that makes up Peruvian fishmeal manufacturing. We first show that quality upgrading is an important motive for vertically integrating. Firms integrate suppliers when the quality premium—the relative price of high quality output—rises for exogenous reasons, but not when average or low quality prices rise. The greater a firm's scope for shifting low to high quality production, the greater its integration response. We then show that integration changes suppliers' production behavior. A given supplier's actions are less geared towards increasing quantity and more geared towards maintaining input quality after the supplier is integrated and loses access to alternative pay-per-kilo buyers. Finally, we show that firms and individual plants that use integrated suppliers at the time of production ultimately produce a significantly higher share of high quality output. In sum, our results suggest that firms change their organizational structure when their output quality objectives change because controlling the incentives of independent suppliers facing a quantity-quality trade-off is difficult, as classical theories of the firm predict.

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# 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.<sup>1</sup> However, as global incomes rise and barriers to trade fall, one potential motive has gained increased relevance: integrating in order to improve product quality. Access to wealthier, quality sensitive markets brings rising returns to output quality,<sup>2</sup> 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 hypothesis 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 simple structure of the sector creates an ideal setting in which to study the relationship between integration and output quality. 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.<sup>3</sup> Furthermore, 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 several 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 each month, providing a direct measure of quality.<sup>4</sup> We can link these input and output quantities to all ex-

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<sup>1</sup>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 (2012) provide excellent overviews of the broader literature on firms’ structure.

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

<sup>3</sup>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).

<sup>4</sup>See Goldberg & Pavcnik (2007); Khandelwal (2010); Hallak & Schott (2011) for discussion of the indirect quality proxies used in the

port 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.<sup>5</sup> 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 driven by fluctuations in the *regulatory fishing quota*-driven supply of high (and low) quality fishmeal in countries other than Peru. 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](#)).<sup>6</sup> [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 the average fine-grained quality grade of a firm’s output, as inferred in exports and auxiliary price data. Our primary measure of integration is the fraction of inputs that are sourced from integrated suppliers

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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.

<sup>5</sup>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.

<sup>6</sup>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 B demonstrates why the presence of other fishmeal manufacturers who value input quality less can make repeated interactions solutions to these challenges infeasible.

("Share VI")—a measure that is closely tied to the hypothesis that integration and output quality are causally linked.<sup>7</sup> Alternatively, we also consider the number of suppliers owned. The relationship we establish holds across each of these measures of a firm's output quality and organizational structure at a given point in time.

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 that vertical integration is used by firms *as a strategy* for increasing output quality. To demonstrate this causally, 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 *quantities* produced by other top exporters. Because the other top exporters specialize in particular quality grades (e.g. Norway produces primarily high quality fishmeal, while Thailand produces primarily low quality), and because their production quantities are driven by country specific regulatory fishing quotas, these quantities 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. When the quality premium is high, firms producing mostly low quality output face strong incentives to shift low to high quality production. Firms already producing mostly high quality output face less strong incentives to do so. The opposite holds when the quality premium is low.

We find that Peruvian manufacturers integrate when their incentives to upgrade quality rise, and vice versa.<sup>8</sup> 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. Our results indicate that quality upgrading itself is an important motive for integrating suppliers.<sup>9</sup>

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)<sup>10</sup>—using GPS-based measures. We show that 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-

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<sup>7</sup>If integration directly affects output quality, it presumably does so through firms' (and individual plants') *production* process—that is, *use of* integrated versus independent suppliers. 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). On *use of* integrated versus independent suppliers, see also, among others, Baker & Hubbard (2003); Breza & Liberman (2017).

<sup>8</sup>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.

<sup>9</sup>Several of the most prominent alternative explanations are also inconsistent with other features of the context we study and auxiliary findings. We show e.g. that 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. Similarly, Peruvian fishmeal manufacturers appear to achieve general supply assurance primarily through repeated interactions with independent suppliers (Martinez-Carrasco, 2017); the quantity supplied by a given supplier to a given firm is *lower* after integration (/before de-integration).

<sup>10</sup>"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).

versus-quality behavior. This result is consistent with a dynamic version of our model—both are shown in Appendix B—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 (Atalay *et al.*, 2014). We show 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*. Though we ultimately cannot rule out that other incentives emanating from organizational structure itself also help explain the impact of integration on supplier behavior, reconciling this finding with pure knowledge transfer theories is challenging.

Our third piece of evidence suggests that vertical integration in fact increases output quality. 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 a leave-firm-supplied-out measure of the local presence of a particular type of supplier that is regulatorily prohibited from being integrated. The presence of such suppliers fluctuates due to natural variation in fish density, weather, and decisions made by their captains. The logic behind the instrument 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.<sup>11</sup> The IV estimates are very similar to 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 firms vertically integrate in order to produce higher quality products, and that the reason they do so appears to be that integration changes supplier behavior in a way that increases output quality.

A natural question is whether our results are specific to Peru’s fishmeal industry. However, 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.<sup>12</sup> In the concluding section of the paper, we document a positive relationship between (a proxy for) the average quality of a given type of manufacturing product a country exports to the U.S. and the average degree of vertical integration among the exporters. This provides suggestive evidence that the relationship between firms’ output quality and organizational structure we establish in this paper may hold more broadly in export manufacturing industries.

Our study bridges and advances the literatures on the boundaries of the firm and quality upgrading.<sup>13</sup> 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 early 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

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<sup>11</sup>Plausible arguments against the exclusion restriction underlying our interpretation of the IV results would 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. The IV results are very similar if we instrument with the total number of independent suppliers present, rather than the subset that is independent by law.

<sup>12</sup>There is a robust relationship between countries’ input-output structure and their level of contract enforcement (Nunn, 2007; Boehm, 2016), and vertical integration is more common in developing countries (Acemoglu *et al.*, 2009; Macchiavello, 2011).

<sup>13</sup>There is also a prominent literature studying the relationship between integration and international trade (Antràs (2014, 2016) provides excellent overviews of this literature), but our focus is on firms’ *domestic* organizational structure.



organizational structure when their output *objectives* change.<sup>14</sup>

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.<sup>15</sup>

Finally, we show 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.<sup>16</sup> 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 Kosova *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.<sup>17</sup>

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, 2017).<sup>18</sup>

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; Fras *et al.*, 2009; Brambilla *et al.*, 2012; Brambilla & Porto, 2016; Brambilla *et al.*, forthcoming), 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.

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<sup>14</sup>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.

<sup>15</sup>We follow Atalay *et al.* (2014) in exploiting changes in integration within supplier-firm pairs. They focus on transfers of knowledge.

<sup>16</sup>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).

<sup>17</sup>Existing empirical papers on firms almost exclusively study *either* the effectiveness of a strategy *or* the determinants of its use.

<sup>18</sup>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 renegeing 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.

## 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. 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 may be large steel boats—which may be independent or owned by the firm that owns the plant—or smaller wooden boats. Regulations prohibit fishmeal firms from owning wooden boats. There are on average 812 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 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.

### 2.2 Product differentiation and quality

An important feature of fishmeal is that *output* quality effectively depends on 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 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,



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 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. 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 45 percent. Firms can generally increase or decrease the total amount of inputs that come 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. Of course, a firm may vary its Share VI also by increasing or decreasing its use of independent suppliers. As seen in Appendix Figure A3, and following the trend in ownership, Share VI slowly increased during our data period—by 2.9 percent from season to season. Approximately 77 percent of this growth came solely from increasing the amount of input coming from integrated suppliers, and the rest from lower total input purchases, as shown in Panel B of Table 2.

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.<sup>19</sup>

## 2.4 Contracting and supplier incentives

There is no centralized spot market for fish purchases: plants are spread out along the coast, in part because the fish move around. Where a boat makes a catch thus constrains the set of ports it can deliver to. 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 Chief Operating Officer, and others in the sector to gain a qualitative understanding of the characteristics of the contracts used and the incentives suppliers face. The interviewees reported that captains of boats owned by fishmeal firms generally are paid a fixed wage, in some cases with a bonus tied to some measure of performance.<sup>20</sup>

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.

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<sup>19</sup>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 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.

<sup>20</sup>The fishmeal industry associations reported that payment schemes vary across firms; that some pay bonuses tied to measures of performance; but that these are on top of a fixed wage and usually small.

## 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 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.<sup>21</sup>

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

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<sup>21</sup>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.

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

$$P = a_1$$

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

with  $\gamma, \delta \geq 0$ .<sup>22</sup> 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.<sup>23</sup> 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<sup>24</sup>, 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  $\alpha$ . 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  $\alpha$  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:

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

<sup>22</sup>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.

<sup>23</sup>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.

<sup>24</sup>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).

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.

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  $\delta$ —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 B](#), 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.  $P \gg Q$ ), 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.<sup>25</sup> 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.

**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.<sup>26</sup>

**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.<sup>27</sup>

## 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 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×export port×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×season level measure, we average protein content across export shipments, weighting by quantity.<sup>28</sup> A priori, we have little reason to

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<sup>25</sup>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).

<sup>26</sup>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.

<sup>27</sup>Only about half of the observations in the Supply transactions dataset can be matched to a GPS recording. Some boat owners, for example, disappear from the GPS data for a complete calendar year. However, such missingness is unlikely to be of concern for within-boat analysis, the level at which we use the GPS data.

<sup>28</sup>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 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

believe that this inferred protein content measure could be systematically biased.<sup>29</sup> 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.

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. 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. Furthermore, 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. Finally, Share VI is 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. Recall from Sub-section 2.3 that Peruvian fishmeal manufacturers generally use integrated suppliers to capacity over the course of a season, so in the context we study, Share VI and supplier ownership are closely related measures of integration.

### 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:

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

where  $\text{Quality}_{it}$  and  $\text{VI}_{it}$  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 technology the firm uses to convert fish into fishmeal,<sup>30</sup>  $\text{HighTech}_{it}$ , and firm and season fixed effects  $\gamma_i$  and  $\delta_t$ . 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 strong baseline relationship between owning suppliers and output quality. The estimates in column 3 imply, for example, that moving from the 25th to 75th per-

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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.

<sup>29</sup>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.

<sup>30</sup>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  $\text{HighTech}_{it}$ , i.e., steam drying (High) technology. At the firm level,  $\text{HighTech}_{it}$  is equal to the share of installed capacity that is of the high type.

centile of number of boats owned is associated with an increase in protein content of just under 10 percent of the range observed in Peru.<sup>31</sup>

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 50 percent higher, and an average protein content that is higher by about 20 percent of the range observed in Peru.

In Panel C we show that these results are not driven by observable, time-varying supplier or firm characteristics. We control for the firm's share of total industry production and a series of supplier characteristics. Doing so has little impact on the estimated coefficient.<sup>32</sup>

In Appendix B, 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 B.

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 rule out such 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 makes clear why this finding is difficult to reconcile with alternative theories.

### 5.1 Estimating how the quality price premium affects vertical integration

In Table 4, we first show that firms as a whole *do* vertically integrate when the quality premium is high and de-integrate when the quality premium is low. We quantify 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. Specifically, if  $VI_{it}$  is defined as Share VI, we analyze  $VI_{it} - VI_{it-1}$ , where  $t$  indicates a season. Column 1

<sup>31</sup>Firms in the 25th percentile own four boats, while firms in the 75th percentile own 36 boats.  $\beta \times (\text{asinh}(36) - \text{asinh}(4)) = 0.43$ . The range of protein content observed in Peru is approximately 63-68 percent.

<sup>32</sup>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 also leaves the magnitude and significance of the coefficient on Share VI essentially unchanged.

shows results from regressing this measure on the quality premium—the difference between the (log) price of high and low quality fishmeal. We control for firm fixed effects and cluster the standard errors at the firm level. The positive and significant estimated coefficient on the quality premium seen in the table does not by itself allow causal conclusions—variation in the quality premium could correlate with other important factors that influence firms’ organizational choices. But the *industry*-wide relationship between integration decisions and the quality premium underscores the general plausibility of the *firm level* causal relationship we establish below.

In column 2 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 average fishmeal price in season  $t$ —replacing the quality premium as the regressor of interest. The estimated coefficient is near zero and insignificant, indicating that firms are not more likely to vertically integrate when the overall price level is high. Figure 2 highlights that the quality premium in Peru is at most weakly correlated with average prices in Peru. It is thus not surprising that firms respond differently to the two.

To isolate *firm-specific* incentives to upgrade quality, we categorize firms based on their *upgradeable share of production*, or the share of their production that is currently low quality and hence could potentially be upgraded. For example, a firm currently producing 25 percent high quality output has a 75 percent *upgradeable share of production*. Our conjecture is that—when the quality premium is high—firms that produce mostly low quality output should face greater incentives to quality upgrade than firms which already produce mostly high quality output. Absent a direct relationship between quality upgrading and vertical integration, we would expect no differential impact on  $VI_{it} - VI_{it-1}$  for these firms. We thus run the following specification:

$$VI_{it} - VI_{it-1} = \alpha + \beta_1 \text{QualityUpgradingIncentives}_{it} + \beta_2 \text{UpgradableShareOfProduction}_{it-1} + \gamma_i + \delta_t + \varepsilon_{it} \quad (2)$$

where  $\text{QualityUpgradingIncentives}_{it}$  is  $\text{UpgradableShareOfProduction}_{it-1} \times \text{QualityPremium}_t$ . Our hypothesis implies that  $\beta_1 > 0$ . We control for  $\text{UpgradableShareOfProduction}_{it-1}$  itself and firm and production season fixed effects  $\gamma_i$  and  $\delta_t$  and cluster the standard errors at firm level.

The approach in (2) 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 of 13 different production seasons, and in each of these 13 seasons the quality premium may be relatively high or relatively low. 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. We thus identify how firms respond to their incentive to produce high rather than low quality output by comparing integration choices *both* during periods when the returns to quality are high and during periods when the returns are low. Additionally, the characteristic that defines a firm’s exposure to the quality premium at a given point in time— $\text{UpgradableShareOfProduction}_{it-1}$ —is itself controlled for.<sup>33</sup>

<sup>33</sup>The fact that we control for the characteristic that defines a firm’s exposure to a “treatment” variable that varies across time—here  $\text{UpgradableShareOfProduction}_{it-1}$ —distinguishes our approach from traditional Bartik instrument approaches (Goldsmith-Pinkham *et al.*, 2017). Note also that firms’ upgradeable share of production evolves over time. Another strength of our approach is thus that the high and low  $\text{UpgradableShareOfProduction}_{it-1}$  firms being compared across one rise or fall in the quality premium may differ

The results in column 3 of Table 4 show 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 and vice versa when the quality premium is low—consistent with our hypothesis and the model in Section 3.

A potential concern is the possibility that the quality premium could be endogenous to individual Peruvian firms’ output quality objectives and organizational structure. To address this concern, we instrument for the quality premium in Peru using the quantities exported by other top fishmeal producing countries that specialize in either high or low quality fishmeal. The total quantities these other countries produce are ideal instruments because they are driven by *aggregate fishing quotas* set by each country’s (and European) regulatory authorities. Aggregate fishing quotas are set based on sustainability considerations so the quantities of fishmeal these other countries produce are unlikely to correlate with factors influencing Peruvian firm’s integration decisions, except via their influence on market prices. In addition, the production volumes of countries that specialize in high or low quality grades generate meaningful variation in the quality premium in Peru—and we know from column 2 of Table 4 that any impact these volumes may ultimately have on integration decisions in Peru does not arise through the general price level.

Specifically, our instruments are the quantities exported in the relevant production season by those of the top 10 fishmeal exporting countries—excluding Peru—for which such quantity data is available, all of which specialize in high or low quality grades.<sup>34</sup> The first stage of our IV approach is the following:

$$\begin{aligned} \text{QualityUpgradingIncentives}_{it} = & \alpha + \sum_c \beta_c \text{UpgradableShareOfProduction}_{it-1} \times \text{Quantity}_{ct} \quad (3) \\ & + \beta_2 \text{UpgradableShareOfProduction}_{it-1} + \gamma_i + \delta_t + \varepsilon_{it} \end{aligned}$$

where  $c$  is an exporter country, and  $\text{UpgradableShareOfProduction}_{it-1} \times \text{Quantity}_{ct}$  are our excluded instruments.  $\text{Quantity}_{ct}$  is quantity of fishmeal exported from country  $c$  in season  $t$ .

The first stage results—shown in Appendix Table A2—are strong, confirming that the total quantities of high and low quality fishmeal produced by countries with aggregate fishing quotas impact the quality premium in Peru.<sup>35</sup>

The second stage results are shown in column 4 of Table 4. The IV estimate of  $\hat{\beta}_1$  is of very similar magnitude to the OLS estimate in column 3. The estimates in column 3 and 4 both imply that, when the quality premium in Peru rises by 10 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.

We argue 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 and low quality fishmeal *locally*, and ultimately in the quality premium in Peru. This is what we find in column 5, where we instrument for the quality premium in Peru using the *quality-grade specific price* in other top exporting countries, rather than the

from those being compared across another rise or fall.

<sup>34</sup>These countries are Chile, Denmark, Iceland, Japan, Norway, and Thailand. Information on total monthly exports from these countries is available from COMTRADE (a dataset described in footnote 48).

<sup>35</sup>Chile, Denmark, Iceland, Japan, and Norway 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), while Thailand introduced such a system in 2015. As noted above, these are the top 10 fishmeal exporting countries for which quantity data is available. Our results are very similar if we instead use only the top five global fishmeal exporters (excluding Peru)—Chile, Denmark, Iceland, and Thailand—and if we exclude Thailand.

quantities exported themselves. The estimates are again nearly identical to the OLS estimates in column 3 and the quantity-based IV estimates in column 4.<sup>36</sup>

In the last column of Table 4, we show that firms' estimated response to  $\text{QualityUpgradingIncentives}_{it}$  does not mask an underlying response to *firm-specific* average prices. We construct the firm-specific average price by weighting low and high quality grade prices by the firm's  $t - 1$  output shares. The results in column 6 underscore that firms do not integrate in response to income shocks that differ across firms because firms produce different shares of high and low quality fishmeal.

In Appendix C 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.<sup>37</sup>

## 5.2 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 (Ordober *et al.*, 1990). If such a story explained our results, 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 supply assurance

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<sup>36</sup>Specifically, column 5 shows results from instrumenting for the quality premium in Peru using the *high quality price* in other top exporting countries. This is because price data is available—from IFFO, an industry association—only for three of the top exporters used in column 4 that all specialize in high quality fishmeal: Chile, Denmark, and Iceland. The results shown in column 5 comes from first running a first stage regression identical to that described in equation (3), but replacing  $\text{Quantity}_{ct}$  with  $\text{HighQualityPrice}_{ct}$ , the high quality price in exporting country  $c$  in season  $t$ . 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. The first stage results in Appendix Table A2 are thus strong. (Note that the reason why high quality prices are not exactly the same across countries is that production seasons differ and the distance between countries would make it difficult to conduct perfect arbitrage.)

<sup>37</sup>We follow many fruitful applications of such an approach in the trade literature (see e.g. Park *et al.*, 2009; Brambilla *et al.*, 2012; Bastos *et al.*, 2018; Tintelnot *et al.*, 2017).



story—namely that firms integrate suppliers to secure general access to inputs but in the process coincidentally produce higher quality output—cannot explain our findings. Such a story is inconsistent with the fact that manufacturers vertically integrate in response to the relative price of high quality output, but not average prices. Another form of supply assurance—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—is exactly the interpretation we favor.

We conclude that manufacturers vertically integrate when the quality premium rises for exogenous reasons *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: 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. 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, not stacking fish high on top of each other, 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 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  $\times$  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.<sup>38</sup> 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,<sup>39</sup> 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:

$$B_{ijt} = \alpha + \beta I[VI \times \text{supplies owner firm}]_{ijt} + \gamma_{ij} + \delta_t + \varepsilon_{ijt} \quad (4)$$

where  $B_{ijt}$  is a measure of the behavior of supplier  $i$ , delivering to plant  $j$ , on date  $t$ .  $I[VI \times \text{supplies owner firm}]_{ijt}$  is an indicator for the supplier being integrated with the plant it delivers to on date  $t$ . We include date fixed effects ( $\delta_t$ ) to control for potential date specific effects and Supplier  $\times$  Plant fixed effects ( $\gamma_{ij}$ ) 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.

Column 1 of Panel A 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, 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. These results suggest that, when integrated, suppliers reduce costly actions associated with long trips, and bring back fresher fish as a result.

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 B1, 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 B. 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.

<sup>38</sup>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.

<sup>39</sup>As shown in Appendix Table A3, the characteristics of integrated suppliers unsurprisingly differ from the characteristics of independent suppliers. On observable features such as the size of the boat, the power of its engine, and whether or not it has a cooling system installed, the average switcher falls in between the average always-independent boat and the average always-integrated boat, but closer to the latter.

## 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  $\times$  plant pair.<sup>40</sup>

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 that it is not the case that firms simply choose to integrate suppliers that have already begun changing their behaviors, providing 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 incentives, the behaviors we see not generating any input quality benefits that manufacturers are aware of and *act on* them. Such a story is difficult to reconcile with this paper's central finding that firms integrate suppliers when the quality premium rises.<sup>41</sup>

## 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 take more input quality-increasing and less input quantity-increasing actions. In this section we show that plants' *output* quality responds to integrating suppliers in exactly the manner we expect if the integration-induced change in supplier behavior improves input quality. This provides empirical support for our model's third prediction, namely that vertical integration is an *effective* organizational strategy for producing high quality output.

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

<sup>40</sup>To implement, we run the same specification as in Equation 4, but define  $I[VI \times \text{supplies owner firm}]$  to be equal to one if the supplier is (i) always owned by a fishmeal firm, and (ii) currently delivering to its parent firm.

<sup>41</sup>Additionally, such a story would raise a conceptual question: if there is no known input quality benefit, and integration lowers input quantity, then why integrate at all?

beyond the firm level evidence discussed in Sub-section 4.3. We then attempt to isolate shifts in a plant's Share VI that occur for exogenous reasons. We show evidence from an IV approach that exploits geographic variation in the local concentration of a particular type of supplier that is regulatorily prohibited from being integrated. In sum the results we present suggest that the Share VI-output quality relationship 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.<sup>42</sup> 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 A4. There we use internal data provided to us by a single major firm.<sup>43</sup>

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 the firm and plant levels. Of course, the fact that these correlations hold for individual plants does not rule out non-causal interpretations. It may be that plant specific shocks, for example to productivity,<sup>44</sup> occur and *independently* affect the quality of a plant's output and the share of the plant's supply coming from integrated suppliers.

To evaluate this alternative explanation, we construct an instrument for a plant's use of integrated suppliers at a particular point in time. We use 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.

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.

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<sup>42</sup>We observe whether each plant has any high technology installed so  $\text{HighTech}_{it}$  is now a dummy variable.

<sup>43</sup>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.

<sup>44</sup>Another example of a shock that may affect different plants within a firm differently is El Niño, which hit Peru in late 2009.

Of course, a plant's quality objectives may themselves influence independent suppliers' whereabouts. The plant may for example request deliveries from independent 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.

The first stage, shown in Appendix Table A5, 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 of the same sign, statistical significance, and general magnitude as the corresponding OLS estimates, only slightly bigger. 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 specification show in Appendix Table A4, which utilizes internal data from the firm that shared its data with us.

Might the composition of neighboring plants' suppliers correlate with the quality of a given plant's output for other reasons than having comparable access to independent suppliers? A time-varying, *port level* component of output quality that correlates with our instrument for other reasons than independent suppliers' inputs lowering output quality is a possible concern. However, beyond the presence of independent suppliers, we find no evidence of a relationship between changes in output quality across different plants within the same port.<sup>45</sup> This result, in combination with the sign we find on the first stage—greater presence of independent suppliers increases use of such suppliers—and the second stage—use of independent suppliers lowers output quality—suggests that our instrument's exclusion restriction holds.<sup>46</sup>

In this section we began by documenting that the firm level relationship between inputs coming from suppliers that are integrated at the time of production and output quality holds also at the plant level, including within firms. We then showed that instrumenting for Share VI yields the same positive, estimated relationship with the quality of a plant's output as OLS regressions.

## 7.2 Interpretation

Our interpretation of the results in this section is that access to inputs from integrated suppliers directly increases output quality because a manufacturer can incentivize suppliers to engage in less quality-decreasing behavior once the suppliers are integrated. This follows the model in Section 3, and is consistent with the results in Section 6. A priori, output quality may of course co-vary with organizational structure without necessarily reflecting a causal relationship. Perhaps the most plausible non-causal links between quality up-

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<sup>45</sup>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.

<sup>46</sup>A priori, it could be that a plant's use of independent suppliers itself affects the number of independent suppliers supplying other plants in the port because firms compete for access to suppliers, or that high fish density near a cluster of plants simultaneously enables plants to produce higher quality fishmeal and attracts independent fishing boats. The first of these scenarios would imply a positive sign on the first stage and the second a negative sign on the second stage—the opposite of what we find.

grading and integration—for example, that growing firms both produce higher quality output and acquire more suppliers for independent reasons—are ruled out as explanations of our findings by the simple OLS regressions in Table 6 and Appendix Table A4: output quality correlates with *use* of integrated suppliers at the time of production across *plants*, including within firms. The IV regressions go a step further by documenting that the same relationship holds when we restrict attention to fluctuations in the use of integrated suppliers that is driven by variation in the local presence of independent suppliers.<sup>47</sup>

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. In Section 5 we showed that one of firms’ explicit motives for integrating suppliers is to produce a higher share of high quality output. Our evidence indicates that vertical integration increases output quality and that, as a result, firms integrate suppliers when the quality premium rises.

## 8 Conclusion

Guided by Holmstrom & Milgrom (1991)’s classical ideas and subsequent theories of the firm characterizing how we expect firm boundaries to respond to the multitasking nature of suppliers’ work (Baker *et al.*, 2001, 2002; Gibbons, 2005a,b), this paper identifies an overlooked motivation for and consequence of vertical integration in incomplete contracts settings: downstream firms integrate to be able to produce output of high enough quality to sell to high-paying consumers abroad. Integration allows manufacturing firms to incentivize quality-increasing behavior from existing suppliers and better control input quality.

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 firms’ returns to shifting from low to high quality production rise for exogenous reasons, they acquire more of their suppliers. This strategy appears to be effective because fishing boats change their behavior in a way consistent with delivering fresher fish when they are acquired by the downstream firm they supply—which helps firms produce higher quality fishmeal. Finally, we show that firms ultimately produce higher quality output when their organizational structure is more vertically integrated.

These results are inconsistent with alternative theories in which the integration-quality relationship reflects third factors that affect both firms’ choice of structure and products produced without the two being directly related. They are also inconsistent with explanations in which 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. Instead, the evidence we present suggests that—while firms

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<sup>47</sup>In Table 3 we also showed that the firm level relationship between vertical integration and output quality holds when we control for the firm’s share of total industry output and supplier characteristics.



vertically integrate for many different reasons—in settings where output quality is vertically differentiated and contracts incomplete, one motive for integration is quality upgrading. That is, integration is an explicit organizational choice made *in order to* “climb” the quality ladder.

A natural next question is the generality of this finding. In Figure 3, we plot a proxy for average quality that is available for most exporter countries—the average unit value of manufacturing products exported to the U.S.—against the share of those exports that is imported by “related party” downstream firms located in the U.S. (a measure of vertical integration). The figure shows clear evidence of an upward-sloping relationship between average unit values and related party import shares. The same relationship holds also within product categories.<sup>48</sup> This suggests that our findings reflect an association between vertical integration and manufacturing output quality that tends to hold on average across countries and industries. We find this unsurprising, as theory suggests that integration can help address the contracting problems that are typical when producing high quality goods. Given this—and despite vertical integration *overall* being common in developing countries (Acemoglu *et al.*, 2009; 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.

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<sup>48</sup>We show this in Appendix Table A6. In Figure 3, the variable plotted on the y-axis is  $\hat{\gamma}_c$  from the regression  $\log(\text{unit value})_{cpt} = \alpha_{pt} + \gamma_c + \varepsilon_{cpt}$ , where  $\log(\text{unit value})_{cpt}$  is the average log unit value of products exported from country  $c$ , of HS6 code  $p$ , in year  $t$  to the U.S.;  $\alpha_{pt}$  is a product×year fixed effect; and  $\gamma_c$  is an origin country fixed effect. This regression is estimated using COMTRADE data from BACI (See Gaulier & Zignago (2010) for a description of the data). The variable plotted on the x-axis is  $\hat{\delta}_c$  from the regression  $\text{Related party share of U.S. imports}_{cpt} = \beta_{pt} + \delta_c + \nu_{cpt}$ , where  $\text{Related party share of U.S. imports}_{cpt}$  is the share of products exported from country  $c$ , of NAICS code  $p$ , in year  $t$  to the U.S. that are imported by related parties (usually other units of the same firm (Ruhl, 2015));  $\beta_{pt}$  is a product×year fixed effect; and  $\delta_c$  is an origin country fixed effect. This regression is estimated using data from the U.S. Census Bureau.

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TABLE 1: SUMMARY STATISTICS

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

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

**TABLE 2: 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: Decomposition of the growth rate of Share of inputs from VI suppliers			
$\text{Growth (Share VI)}_{i,t} \approx \log\left(\frac{\text{Share VI}_{i,t+1}}{\text{Share VI}_{i,t}}\right) = \log\left(\frac{\frac{\text{VI}_{i,t+1}}{\text{Total}_{i,t+1}}}{\frac{\text{VI}_{i,t}}{\text{Total}_{i,t}}}\right) = \underbrace{\log\left(\frac{\text{VI}_{i,t+1}}{\text{Total}_{i,t+1}}\right)}_A - \underbrace{\log\left(\frac{\text{Total}_{i,t+1}}{\text{Total}_{i,t}}\right)}_B$			
	Total	A (Boats purchases or sales)	B (Buying less from Indep.)
Growth	2.1%	1.4%	0.7%
Relative Contribution		67%	33%

**Notes:** Panel A displays basic statistics on boat purchases and sales. In Panel B, the growth rate of “Share  $\text{VI}_{i,t}$ ” – the share of the inputs sourced by firm  $i$  during production season  $t$  that comes from vertically integrated suppliers – can be decomposed as presented in the first row of this table.  $\text{VI}_{i,t}$  and  $\text{Total}_{i,t}$  is respectively the *amount* of inputs firm  $i$  sources from vertically integrated suppliers and in total during season  $t$ , and  $\text{Total}_t$  is the total amount of inputs sourced by the industry as a whole during season  $t$ . Term A can then be interpreted as the contribution to the growth rate of Share  $\text{VI}_{i,t}$  that comes from increasing solely the (relative) amount of inputs coming from integrated suppliers. Since boats fish all their individual quota during the course of a season, the only way to increase (decrease) this term is by acquiring (selling) suppliers. Term B can be interpreted as the contribution of a firm decreasing the (relative) amount of inputs sourced from all suppliers. The table gives the growth rate of “Share  $\text{VI}_{i,t}$ ”, Term A and Term B.

**TABLE 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)	0.056 (0.060)	0.043 (0.042)	0.197** (0.083)	0.167** (0.066)	
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	

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	0.377*** (0.166)	0.375** (0.164)	0.982*** (0.293)	1.040*** (0.283)	
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	

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	0.313* (0.159)	0.373** (0.148)	0.313* (0.159)	1.153** (0.457)	0.936*** (0.260)	1.190** (0.461)
Share of inputs from steel boats	-0.098 (0.164)		-0.092 (0.161)	-1.152 (0.808)		-1.153 (0.794)
Share of inputs from boats with high capacity	0.152 (0.166)		0.139 (0.164)	0.988 (1.003)		1.036 (0.976)
Share of inputs from boats with cooling system	0.191 (0.123)		0.202 (0.124)	-0.232 (0.979)		-0.282 (0.986)
Share of industry's production		-0.807 (0.925)	-0.748 (0.891)		1.799 (3.869)	1.889 (3.930)
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	0.75	65.7	65.7
N	275	275	275	208	208	208

**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. *Protein content* is the quantity weighted average of a measure of quality inferred from a database that provides weekly prices by quality. *Share of inputs from VI suppliers* is the share of a firm's inputs that come from VI suppliers during a season. 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. *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 (1)	OLS (2)	OLS (3)	IV (4)	IV (5)	OLS (6)
Quality Premium	0.265** (0.114)					
Log(Average Price)		0.030 (0.052)				
Upgradable share of production (t-1) × Quality premium			3.014** (1.091)	3.006** (1.092)	3.382*** (1.050)	
Firm specific price (weighted by past production)						-1.225* (0.596)
Upgradable share of production (t-1)	No	No	Yes	Yes	Yes	No
Season FEs	No	No	Yes	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes	Yes	Yes	Yes
Mean of Dep. Var.	0.01	0.01	0.01	0.01	0.01	0.01
N	190	190	190	190	190	190
Kleibergen-Paap LM p-value (Under-id)				0.01	0.01	
Kleibergen-Paap Wald F statistic (Weak inst)				10 <sup>6</sup>	38.3	

**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. 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  $\text{Log}(\text{High Quality}) - \text{Log}(\text{Low Quality})$  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. *Log(Average Price)* is the Log of the average price of Peruvian fishmeal, again computed in the month preceding the current fishing season. *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. *Firm specific price (weighted by past production)* is equal to:  $\text{Low quality share of production}_{i,t-1} \times \text{Log}(\text{Low quality price})_t + \text{High quality share of production}_{i,t-1} \times \text{Log}(\text{High quality price})_t$  where  $\text{Low quality share of production}_{i,t-1}$  is the share of firm  $i$ ’s production that was of low quality in the previous season and  $\text{Log}(\text{Low quality price})_t$  is the price of low quality fishmeal in the month preceding the current fishing season. 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*** (0.023)	-0.054*** (0.019)	-0.030* (0.016)
Date FEs	Yes	Yes	Yes
Supplier × Plant FEs	Yes	Yes	Yes
N	315,442	137,278	159,724
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]	-0.147*** (0.027)	-0.082*** (0.026)	-0.073*** (0.023)
Date FEs	Yes	Yes	Yes
Supplier × Plant FEs	Yes	Yes	Yes
N	315,442	137,274	159,724

**Notes:** 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. The number of observations varies from one column to the next as GPS variables for a given trip are sometimes missing. In panel A, we define 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. Standard errors clustered at the boat level are included in parentheses. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

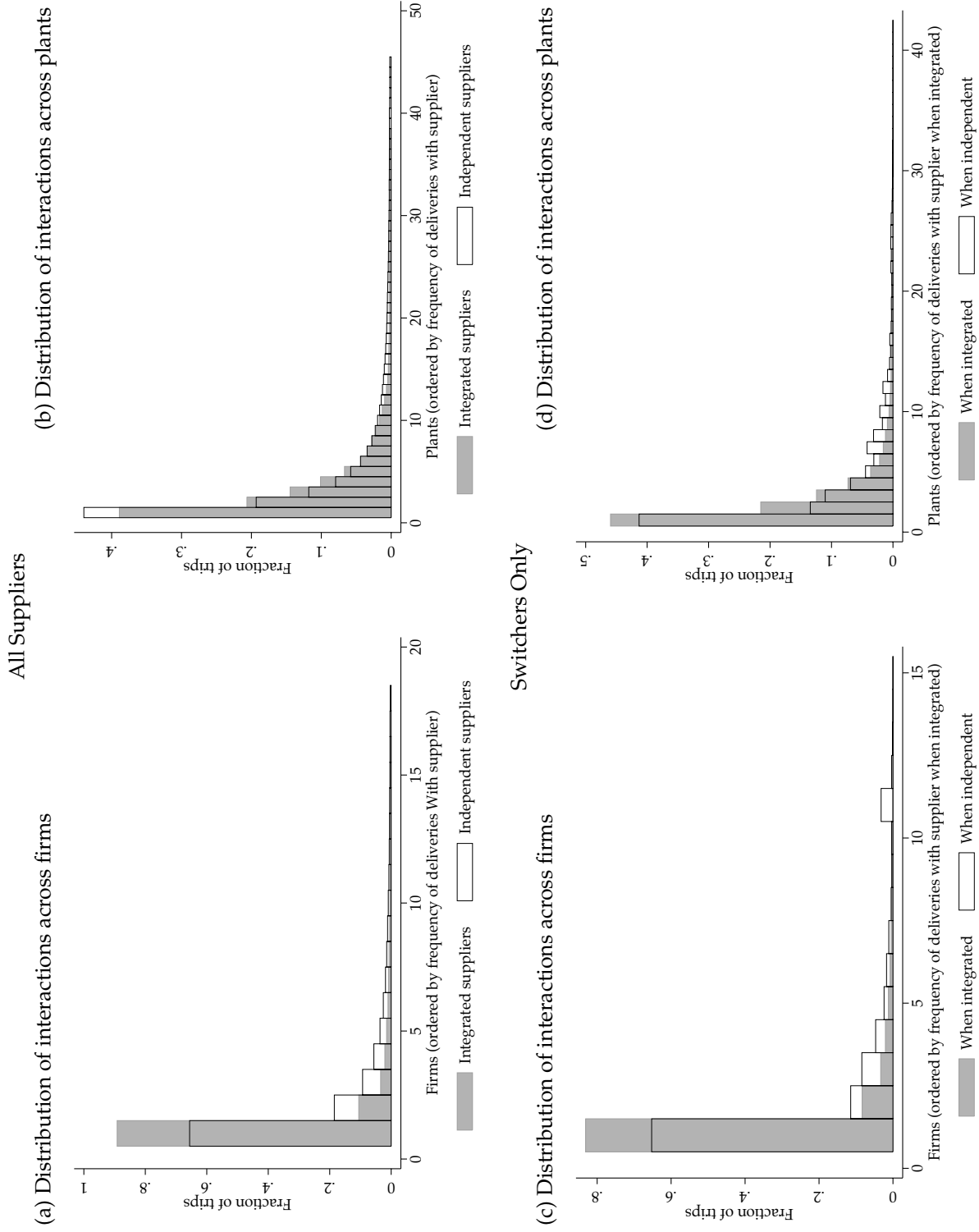
**TABLE 6: OUTPUT QUALITY AND SHARE OF INPUTS FROM VERTICALLY INTEGRATED SUPPLIERS**

Dep. var:	Impact of Share of VI Inputs on Quality					
	High Quality Share of Production					
	OLS (1)	OLS (2)	IV: Ind. Boats (3)	IV: Ind. Boats (4)	IV: Wooden Boats (5)	IV: Wooden Boats (6)
Share of inputs from VI suppliers	0.102** (0.038)	0.064** (0.030)	0.213*** (0.080)	0.169** (0.068)	0.160*** (0.060)	0.142** (0.060)
Has high technology	No	Yes	No	Yes	No	Yes
Month FEs	Yes	Yes	Yes	Yes	Yes	Yes
Plant FEs	Yes	Yes	Yes	Yes	Yes	Yes
Mean of Dep. Var.	0.85	0.85	0.85	0.85	0.85	0.85
N	2647	2647	2487	2487	2647	2647

**Notes:** One observation is a plant in a particular month. *High Quality share of production* is the share of a firm'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 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. 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 season 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 season in question, excluding those that interact directly with the plant itself. Standard errors are clustered at the firm level. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

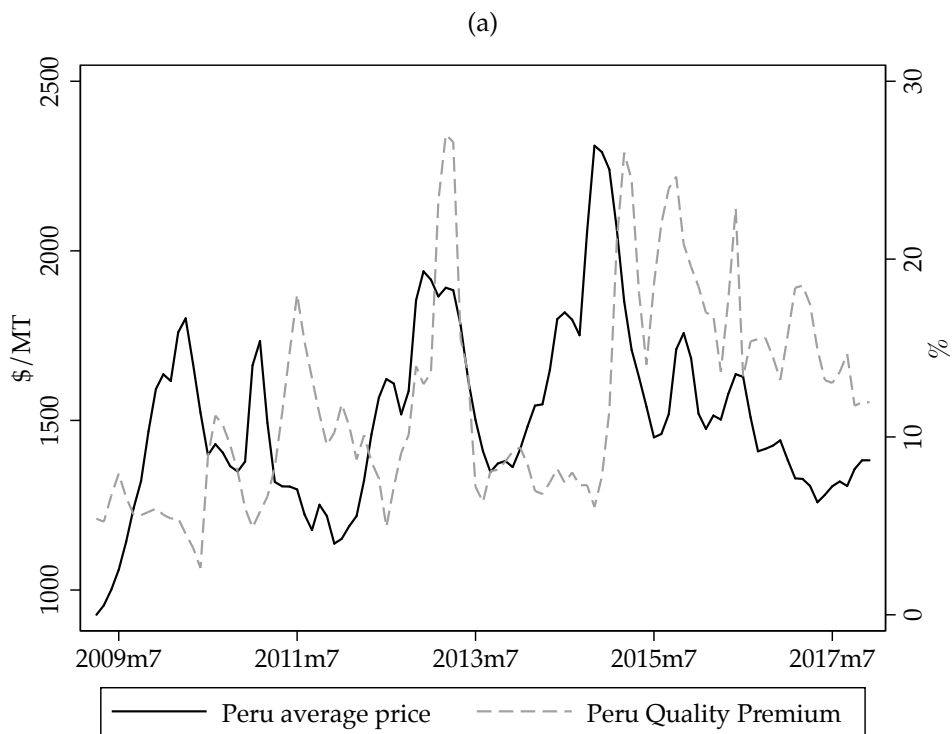


**FIGURE 1: INTERACTIONS BETWEEN MANUFACTURERS AND INTEGRATED AND INDEPENDENT SUPPLIERS**



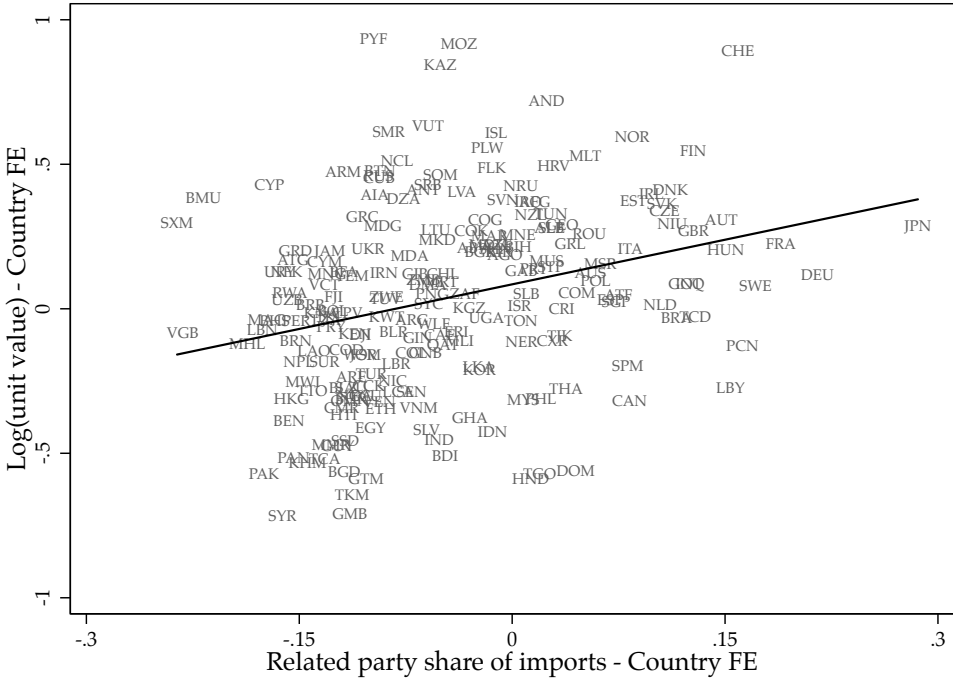
**Notes:** Figures above show the average fraction of deliveries at each firm and plant for independent and integrated suppliers. In figures (a) and (b), plants or firms are ordered based on the frequency of deliveries for each boat x boat owner pair: the plant or firm that receives the highest number 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 average fishmeal price in Peru (the average between the price of “Prime” and “FAQ” fishmeal grades) and the Quality Premium in Peru. *Quality premium* is equal to  $\text{Log}(\text{High Quality}) - \text{Log}(\text{Low Quality})$  where High and Low Quality are the average prices of “Prime” and “FAQ” fishmeal grades respectively.

FIGURE 3: COUNTRIES' OUTPUT QUALITY AND VERTICAL INTEGRATION IN EXPORT MANUFACTURING



Notes: In this Figure, the variable plotted on the y-axis is  $\hat{\gamma}_c$  from the regression  $\log(\text{unit value})_{cpt} = \alpha_{pt} + \gamma_c + \varepsilon_{cpt}$ , where  $\log(\text{unit value})_{cpt}$  is the average log unit value of products exported from country  $c$ , of HS6 code  $p$ , in year  $t$  to the U.S.;  $\alpha_{pt}$  is a product  $\times$  year fixed effect; and  $\gamma_c$  is an origin country fixed effect. This regression is estimated using COMTRADE data from BACI (See [Gaulier & Zignago \(2010\)](#) for a description of the data). The variable plotted on the x-axis is  $\hat{\delta}_c$  from the regression Related party share of U.S. imports  $_{cpt} = \beta_{pt} + \delta_c + u_{cpt}$ , where Related party share of U.S. imports  $_{cpt}$  is the share of products exported from country  $c$ , of NAICS code  $p$ , in year  $t$  to the U.S. that are imported by related parties (usually other units of the same firm ([Ruhl, 2015](#)));  $\beta_{pt}$  is a product  $\times$  year fixed effect; and  $\delta_c$  is an origin country fixed effect. Related party share of U.S. imports  $_{cpt}$  is constructed using data from the U.S. Census Bureau. The data is from 2005 to 2014.

## Appendix 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	4266	66.06	1.60
GERMANY	972	65.42	1.62
JAPAN	545	66.12	1.69
CHILE	305	66.60	1.51
VIETNAM	277	65.91	1.59
TAIWAN	248	66.02	1.71
UNITED KINGDOM	147	65.26	1.62
TURKEY	128	64.91	1.52
INDONESIA	94	66.16	1.64
SPAIN	90	65.44	1.61
AUSTRALIA	85	66.06	1.80
CANADA	66	65.76	1.52
FRANCE	55	65.59	1.72
SOUTH KOREA	24	66.56	1.46
ITALY	21	64.97	1.52
BULGARIA	15	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: VERTICAL INTEGRATION AND THE QUALITY PRICE PREMIUM – FIRST STAGE**

First stage		
Dep. var:	Upgradable share of production (t-1) × Quality Premium	
	(1)	(2)
Upgradable share of production (t-1) × [Log(Qty exp. by Chile)] (t-1)	0.331*** (0.015)	
Upgradable share of production (t-1) × [Log(Qty exp. by Denmark)] (t-1)	0.021*** (0.005)	
Upgradable share of production (t-1) × [Log(Qty exp. by Iceland)] (t-1)	0.124*** (0.005)	
Upgradable share of production (t-1) × [Log(Qty exp. by Japan)] (t-1)	-0.046*** (0.002)	
Upgradable share of production (t-1) × [Log(Qty exp. by Norway)] (t-1)	-0.222*** (0.001)	
Upgradable share of production (t-1) × [Log(Qty exp. by Thailand)] (t-1)	0.173*** (0.001)	
Upgradable share of production (t-1) × [Log(Chile Price)]		0.663*** (0.090)
Upgradable share of production (t-1) × [Log(Denmark Price)]		-2.253*** (0.558)
Upgradable share of production (t-1) × [Log(Iceland Price)]		1.276*** (0.426)
Upgradable share of production (t-1)	Yes	Yes
Season FEs	Yes	Yes
Firm FEs	Yes	Yes

**Notes:** Results from the first stage of IV specifications reported in Table 4. One observation is a firm during a production season. *Quality premium* is equal to  $\text{Log}(\text{High Quality}) - \text{Log}(\text{Low Quality})$  where High and Low Quality are the average price of “Prime” and “FAQ” fishmeal in the month preceding the current fishing season. 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 Column 1, the instruments are Upgradable share of production( $t - 1$ ) interacted with the quantity exported by the top fishmeal exporting countries (excluding Peru) for which there is a national fishing quota. In column 2, the instruments are Upgradable share of production( $t - 1$ ) interacted with average export prices in other high quality fishmeal exporting countries for which the data was available. Standard errors clustered at the firm level are included in parentheses. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

**TABLE A3: 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 (16.24)	0.00 (0.06)	65.73 (27.34)	215.40 (94.78)	56.10 (7.74)
Steel - Independent	104.03 (40.77)	0.09 (0.28)	219.30 (84.35)	412.31 (189.82)	81.15 (13.43)
Steel - Switchers	148.88 (0.43)	0.25 (0.444)	301.18 (129.92)	616.30 (328.51)	92.25 (15.37)
Steel - VI	181.62 (68.13)	0.34 (0.47)	382.00 (137.11)	769.96 (352.52)	97.29 (12.62)

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



**TABLE A4: OUTPUT QUALITY AND SHARE OF INPUTS FROM VERTICALLY INTEGRATED SUPPLIERS - ROBUSTNESS CHECKS USING A MAJOR FIRM IN THE PERUVIAN FISHMEAL INDUSTRY.**

Impact of Share of VI on Quality				
Dep. var:	Protein Content			
	OLS: Ind. Boats		IV: Ind. Boats	
	(1)	(2)	(3)	(4)
Share of inputs from VI suppliers	1.369** (0.654)	1.338** (0.656)	1.469* (0.807)	1.390 (0.918)
Has high technology	No	Yes	No	Yes
Month FEs	Yes	Yes	Yes	Yes
Plant FEs	Yes	Yes	Yes	Yes
N	2487	2487	2647	2647
First Stage				
Dep. var:	Share of Inputs from VI Suppliers			
	(1)	(2)	(3)	(4)
Number of Independent Boats in Port			-0.000 (0.000)	-0.000 (0.000)
Share of Independent Boats in Port			-0.412** (0.200)	-0.398* (0.207)
Kleibergen-Paap LM p-value (Under-id)			0.005	0.006
Kleibergen-Paap Wald F statistic (Weak inst)			3.61	3.06
Anderson-Rubin Wald test p-value			0.24	0.31

**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 A5: OUTPUT QUALITY AND SHARE OF INPUTS FROM VERTICALLY INTEGRATED SUPPLIERS - FIRST STAGE**

Dep. var:	First Stage			
	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*** (0.000)	-0.001*** (0.000)		
Number of Wooden Boats in Port (Leave-Out)			-0.002*** (0.000)	-0.002*** (0.000)
Kleibergen-Paap LM p-value (Under-id)	0.011	0.011	0.010	0.010
Kleibergen-Paap Wald F statistic (Weak inst)	23.55	23.73	27.69	27.69
Anderson-Rubin Wald test p-value	0.01	0.01	0.01	0.01
Has high technology	No	Yes	No	Yes
Month FEs	Yes	Yes	Yes	Yes
Plant FEs	Yes	Yes	Yes	Yes
N	2487	2487	2647	2647

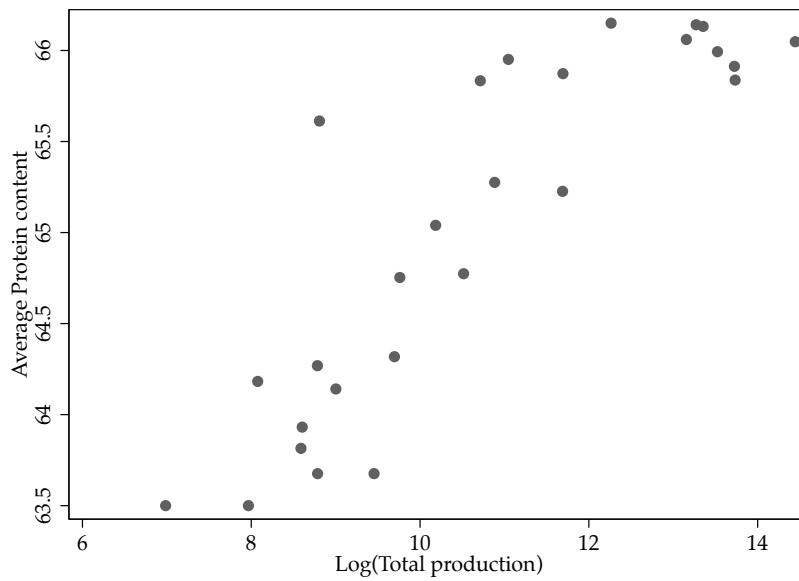
**Notes:** Results from the first stage of IV specifications reported in Table 6. One observation is a plant in a particular month. *Share of inputs from VI suppliers* is the share of a firm's inputs that come from VI suppliers during a season. *Has high technology* is a dummy variable equal to one if the plant in question has any steam drying technologies installed. Columns 1 and 2 instrument 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 instrument 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. Standard errors are clustered at the firm level. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

**TABLE A6: COUNTRIES' OUTPUT QUALITY AND VERTICAL INTEGRATION IN EXPORT MANUFACTURING**

Dep. var:	Log(unit value) - Residuals from HS6×Year FEs and Country FEs
	(1)
Related party share of imports - Residuals from HS6×Year FEs and Country FEs	0.038*** (0.007)
N	208 024

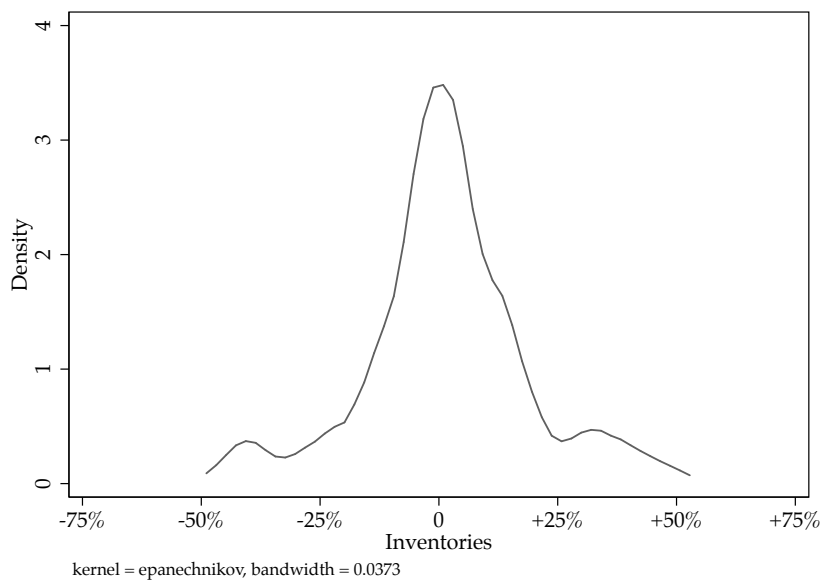
**Notes:** In this table, the dependent variable is  $\varepsilon_{cpt}$  from the regression  $\log(\text{unit value})_{cpt} = \alpha_{pt} + \gamma_c + \varepsilon_{cpt}$ , where  $\log(\text{unit value})_{cpt}$  is the average log unit value of products exported from country  $c$ , of HS6 code  $p$ , in year  $t$  to the U.S.;  $\alpha_{pt}$  is a product×year fixed effect; and  $\gamma_c$  is an origin country fixed effect. This regression is estimated using COMTRADE data from BACI (See [Gaulier & Zignago \(2010\)](#) for a description of the data). The independent variable is  $v_{cpt}$  from the regression  $\text{Related party share of U.S. imports}_{cpt} = \beta_{pt} + \delta_c + v_{cpt}$ , where  $\text{Related party share of U.S. imports}_{cpt}$  is the share of products exported from country  $c$ , of NAICS code  $p$ , in year  $t$  to the U.S. that are imported by related parties (usually other units of the same firm ([Ruhl, 2015](#)));  $\beta_{pt}$  is a product×year fixed effect; and  $\delta_c$  is an origin country fixed effect.  $\text{Related party share of U.S. imports}_{cpt}$  is constructed using data from the U.S. Census Bureau. Because the product level  $c$  (HS6) for the unit value residual is different from the product level  $p$  (NAICS) from the share of related party imports residuals, we compute the value weighted unit value residual at the  $p$  (NAICS) level using a HS6-NAICS conversion table. This regression includes data from 2005 to 2014. Robust standard errors in parenthesis. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

**FIGURE A1: AVERAGE OUTPUT QUALITY AND FIRM SIZE**



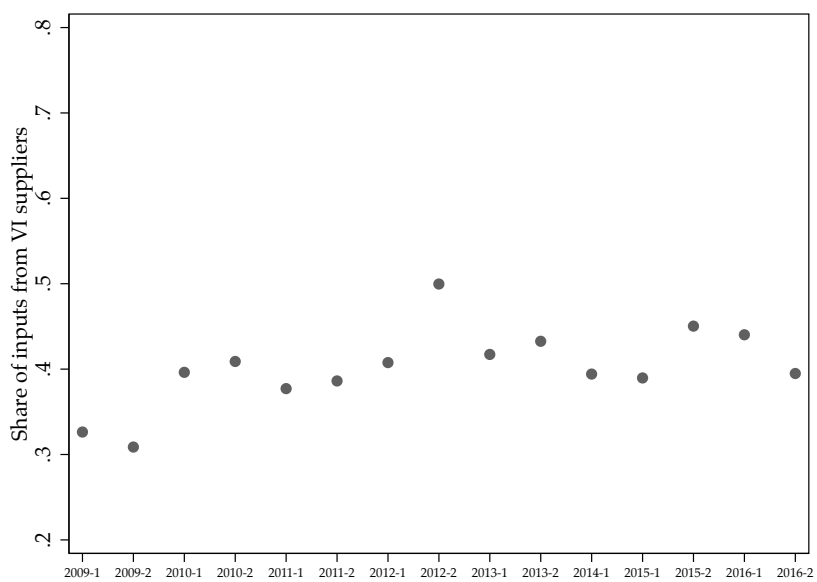
**Notes:** Each dot represents one fishmeal firm in our sample. Total production is the total weight of fishmeal the firm produced during our data period and average protein content is the quantity weighted average protein content of the firm's fishmeal exports.

**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).

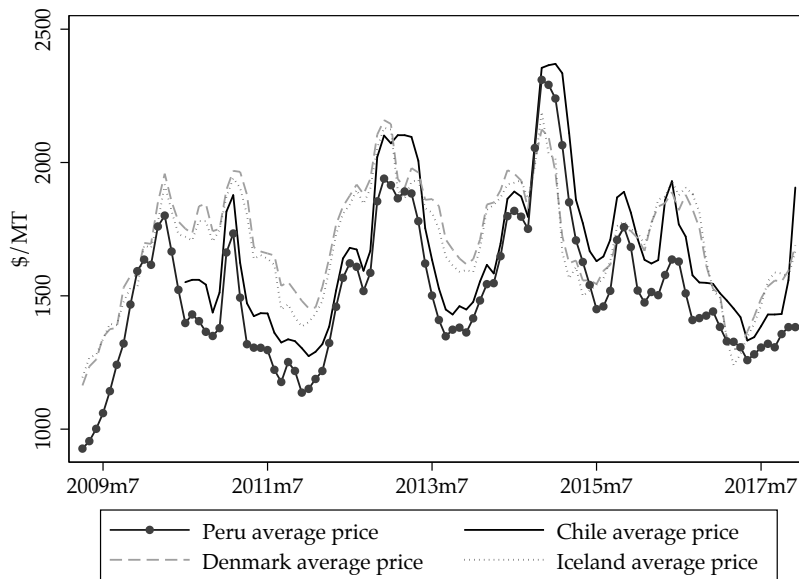
**FIGURE A3: EVOLUTION OF THE VERTICALLY INTEGRATED SHARE OF INPUTS INDUSTRY-WIDE**



**Notes:** This graph shows 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.

# Appendix B 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  $\epsilon$  is orthogonal to any action taken by the upstream party<sup>49</sup>. We assume that  $\epsilon = \bar{\epsilon}$  with probability  $\frac{1}{2}$  and  $\epsilon = -\bar{\epsilon}$  with probability  $\frac{1}{2}$  and that  $\epsilon$  is known by the upstream party at the time of delivery of the inputs.<sup>50</sup>

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).<sup>51</sup> 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.<sup>52</sup> 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)

<sup>49</sup>We could also assume uncertainty over the realization of the  $Q$  surplus, but it would not change the intuition of the result below.

<sup>50</sup>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.

<sup>51</sup>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.

<sup>52</sup>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  $Q$ <sup>53</sup>.

### 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:

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

It is straightforward to see that the first best can only be achieved if the contract is of the form  $b(Q(a_1, a_2)) = Q(a_1, a_2) - t$ , where  $t$  is a transfer independent 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  $\{a_1^*, a_2^*\}$ <sup>54</sup>.

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  $S^{SE} > S^{SO}$ ,<sup>55</sup> 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

<sup>53</sup>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.

<sup>54</sup>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

<sup>55</sup>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:

$$b(Q) + \frac{1}{r}U^{RE} \geq \frac{1}{r}U^{SE} \quad (5)$$

Similarly, 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:

$$\frac{1}{r}D^{RE} \geq b(Q) + \frac{1}{r}D^{SE} \quad (6)$$

Summing (5) and (6), and noting that  $S^X = U^X + D^X$ , we get the following necessary condition:

$$S^{RE} \geq S^{SE} \quad (7)$$

(7) is actually sufficient as well as necessary, because a transfer  $t$  can always be chosen so that when (7) is satisfied, (5) and (6) are also satisfied<sup>56</sup>.

As  $S^{RE} = S^* = Q_0 + \frac{1}{2}\delta^2$  and  $S^{SE} = S^* = Q_0$ , (7) 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  $\pi$ , 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  $\alpha$  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:

$$b(Q) + \frac{1}{r}U^{RO} \geq (1 - \alpha)P + \alpha\tilde{Q} + \frac{1}{r}U^{SE} + \pi \quad (8)$$

The timing of renegeing 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:

$$\frac{1}{r}D^{RE} \geq b(Q) + \frac{1}{r}D^{SE} - \pi \quad (9)$$

If (8) holds for all  $P$  and  $\tilde{Q}$ , then it must hold for the maximum value of  $(1 - \alpha)P + \alpha\tilde{Q}$ . Summing (8) and (9) we get the following necessary condition:

$$\frac{1}{r}S^{RO} \geq \frac{1}{r}S^{SE} + \max\{(1 - \alpha)P + \alpha\tilde{Q}\} \quad (10)$$

Evaluated at  $\{a_1^*, a_2^*\}$ , (10) is equivalent to:

---

<sup>56</sup>For both (5) and (6) to be satisfied and the supplier to accept the contract, it must be that  $Q_0 + \frac{1}{2}\frac{r}{1+r}\delta^2 \leq t \leq Q_0 + \frac{1}{2}\delta^2$

$$(1 - \alpha\gamma - \alpha)\bar{\epsilon} \leq \frac{1}{2r}\delta^2 - \alpha Q_0 \quad (11)$$

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 B1, 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 B2, 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  $\delta$  increases), integrated suppliers will choose a higher level of the 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 a low or high quality output.

We first estimate the following equation:

$$\begin{aligned} B_{ijt} = & \alpha + \beta_1 I[\text{VI} \times \text{supplies owner firm}]_{ijt} \times I[\text{Low Quality}]_{jt} \\ & + \beta_2 I[\text{VI} \times \text{supplies owner firm}]_{ijt} \times I[\text{High Quality}]_{jt} \\ & + \gamma_{ij} \times I[\text{High Quality}]_{jt} + \gamma_{ij} \times I[\text{Low Quality}]_{jt} + \delta_t + \varepsilon_{ijt} \end{aligned} \quad (12)$$

where  $I[\text{Low Quality}]_{jt}$  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  $I[\text{High Quality}]_{jt}$ ).<sup>57</sup> We include Supplier  $\times$  Plant  $\times$  Quality level fixed effects (that is,  $\gamma_{ij} \times I[\text{High Quality}]_{jt}$  and  $\gamma_{ij} \times I[\text{Low Quality}]_{jt}$ ) to focus on the supplier's *differential* response to the plant's input needs when integrated. The other variables are as defined in equation (4).

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 B3 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.<sup>58</sup> 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.

<sup>57</sup>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.

<sup>58</sup>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 B1: 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 (0.007)	0.016* (0.009)	-0.000 (0.006)
Date FEs	Yes	Yes	Yes
Supplier × Plant FEs	Yes	Yes	Yes
N	315,442	137,278	159,724
Panel B: Relational Outsourcing = more than 10 interactions with the same firm for at least 3 consecutive production seasons			
Dep. var:	Log(Quantity supplied)	Log(Max. distance from the plant's port)	Log(Total time spent at sea)
	(1)	(2)	(3)
I[Relational × supplies relational firm]	-0.009 (0.020)	0.026 (0.022)	0.002 (0.015)
Date FEs	Yes	Yes	Yes
Supplier × Plant FEs	Yes	Yes	Yes
N	315,442	137,278	159,724

**Notes:** One observation is a boat during a fishing trip. *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 from one column to the next 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 2 consecutive fishing seasons. In Panel B, we define an independent boat as being under a relational contract if the boat interacts more than 10 times (25th percentile) with the same firm during a fishing season and so, for at least 3 consecutive fishing seasons. Because use 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 B2: OUTPUT QUALITY AND SHARE OF INPUTS FROM VERTICALLY INTEGRATED SUPPLIERS AND SUPPLIERS UNDER A RELATIONAL OUTSOURCING CONTRACT**

Panel A: First definition of relational contracts				
Dep. var:	High Quality share of prod.		Protein content	
	(1)	(2)	(3)	(4)
Share of inputs from VI suppliers	0.343** (0.153)	0.372** (0.161)	0.950** (0.348)	1.039*** (0.333)
Share of inputs from relational suppliers	-0.100 (0.093)	-0.009 (0.065)	-0.159 (0.520)	-0.003 (0.430)
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

Panel B: Second definition of relational contracts				
Dep. var:	High Quality share of prod.		Protein content	
	(1)	(2)	(3)	(4)
Share of inputs from VI suppliers	0.395** (0.164)	0.395** (0.162)	0.949*** (0.265)	0.997*** (0.250)
Share of inputs from relational suppliers	-0.424*** (0.141)	-0.481*** (0.131)	0.809 (2.015)	1.076 (1.812)
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

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

**TABLE B3: SUPPLIER BEHAVIOR, VERTICAL INTEGRATION AND OUTPUT QUALITY**

Dep. var:	Panel A		
	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)	0.017 (0.047)	-0.013 (0.031)
I[VI × supplies owner firm] × I[Plant producing high quality]	-0.066** (0.029)	-0.067*** (0.026)	-0.042** (0.019)
Date FEs	Yes	Yes	Yes
Supplier × Plant × High Quality FEs	Yes	Yes	Yes
N	314,383	136,538	158,918
p-val - Test: two coefficients equal	0.00	0.03	0.04

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

## Appendix C 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.

### C.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.<sup>59</sup> 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. An industry association informed us that almost all contracts for a given season’s production are negotiated either before the season starts, or early in the season.

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

$$VI_{it} = \alpha + \beta_1 \text{Quality}_{it} + \gamma_i + \delta_t + \varepsilon_{it} \quad (13)$$

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.* (2009); Brambilla *et al.* (2012)). In the first stage, quality grade produced is instrumented by demand shocks from specific destinations as follows:

$$\text{Quality}_{it} = \gamma_i + \delta_t + \sum_j \beta_j (I_{i,\bar{t}}^j S_{-i,t}^j) + \varepsilon_{it} \quad (14)$$

where  $j$  is an export destination country, and  $I_{i,\bar{t}}^j S_{-i,t}^j$  are our excluded instruments.  $I_{i,\bar{t}}^j$  is a dummy variable equal to one if firm  $i$  exports to destination  $j$  at least once during our analysis period.  $S_{-i,t}^j$  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  $S_{-i,t}^j$  and  $I_{i,\bar{t}}^j$ . A high  $\beta_j$  should

<sup>59</sup>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.

represent a high quality importer country. We present the results of this specification in columns 3 and 4 of Appendix Table C1).

In an alternative approach (presented in columns 5 and 5 of Appendix Table C1), we replace  $S_{-i,t}^j$  by  $Quality_{-i,t}^j$ , 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  $\beta_j$  represents a high willingness of Peruvian firms to respond to the higher demand for quality expressed by other countries. Conversely, a negative  $\beta_j$  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.

## C.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.<sup>60</sup>

The OLS and the second stage IV results are reported in Appendix Table C1. 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 C1 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.<sup>61</sup> The first stage results are reported in Appendix Table C1<sup>62</sup>.

Since the existing literature that uses destination country demand shocks for identification often struggles with weak instruments, we compute the Kleibergen-Paap and Anderson-Rubin Wald test statistics. Comparing the statistics reported in Table 4 to the Stock-Yogo critical values<sup>63</sup>, while we do not pass the

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<sup>60</sup>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.

<sup>61</sup>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.

<sup>62</sup>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.

<sup>63</sup>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.

Kleibergen-Paap under-identification 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 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 C1: VERTICALLY INTEGRATED SHARE OF INPUTS AND OUTPUT QUALITY - INSTRUMENTING WITH FIRM-SPECIFIC DEMAND SHOCKS**

Dep. var:	Share of inputs from VI suppliers					
	OLS (1)	OLS (2)	IV (3)	IV (4)	IV (5)	IV (6)
Protein content	0.028* (0.014)	0.031** (0.013)	0.060* (0.034)	0.061* (0.033)	0.039* (0.023)	0.042* (0.024)
Log(Sales)		-0.013 (0.014)		-0.031 (0.019)		-0.020 (0.016)
Season FEs	Yes	Yes	Yes	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes	Yes	Yes	Yes
Mean of Dep. Var.	0.30	0.30	0.30	0.30	0.30	0.30
N	192	192	192	192	192	192

Dep. var:	First Stage Protein Content					
	(1)	(2)	(3)	(4)	(5)	(6)
China - HUANGPU			-2.029 (1.570)	-1.152 (1.493)	-5.563*** (1.983)	-5.125** (1.878)
China - SHANGHAI			0.380 (1.066)	0.801 (1.159)	-1.705** (0.792)	-1.843** (0.771)
Germany			-0.219*** (0.057)	-0.214*** (0.053)	-0.037*** (0.005)	-0.040*** (0.006)
China - other			-1.791** (0.721)	-1.922*** (0.690)	-0.406 (0.284)	-0.155 (0.311)
Japan			-0.175 (0.573)	-0.454 (0.417)	-0.166 (0.215)	-0.207 (0.259)
China - DALIAN			-0.168 (0.648)	0.298 (0.570)	0.024 (0.165)	0.008 (0.159)
Chile			0.392*** (0.139)	0.405*** (0.126)	0.078*** (0.022)	0.078*** (0.022)
Vietnam			0.124 (0.372)	0.111 (0.319)	0.321*** (0.102)	0.253** (0.122)
Taiwan			0.108* (0.057)	0.098* (0.054)	0.039*** (0.005)	0.040*** (0.004)
United Kingdom			0.020 (0.135)	0.010 (0.124)	0.004 (0.006)	0.010 (0.007)
Turkey			-0.004 (0.031)	-0.016 (0.038)	-0.001 (0.004)	-0.002 (0.006)
Indonesia			0.435 (0.261)	0.357 (0.225)	0.191 (0.158)	0.101 (0.087)
Spain			0.310* (0.177)	0.295 (0.192)	-0.064 (0.127)	-0.014 (0.146)
Australia			0.048 (0.038)	0.056 (0.033)	0.002 (0.005)	0.000 (0.004)
Canada			-0.135 (0.292)	-0.239 (0.268)	0.015 (0.104)	0.012 (0.093)
France			-0.600* (0.336)	-0.498 (0.302)	-0.232 (0.161)	-0.145 (0.090)
Greece			0.000 (0.011)	-0.001 (0.012)	0.002 (0.003)	0.001 (0.003)
Korea, Rep			0.021 (0.021)	-0.003 (0.021)	0.007 (0.005)	0.004 (0.005)
Italy			-0.007 (0.016)	-0.003 (0.018)	0.004 (0.003)	0.004 (0.003)
Bulgaria			0.020 (0.017)	0.015 (0.018)	0.001 (0.003)	0.001 (0.003)
Firm FEs			Yes	Yes	Yes	Yes
Season FEs			Yes	Yes	Yes	Yes
Log(Sales)			No	Yes	No	Yes
Kleibergen-Paap LM p-value (Under-id)			0.53	0.46	0.53	0.45
Kleibergen-Paap Wald F statistic (Weak inst)			527.3	504.0	962.6	671.75
Anderson-Rubin Wald test p-value			0.00	0.00	0.00	0.00

**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 destination in the relevant season (columns 5 and 6). Standard errors clustered at the firm level are included in parentheses \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .