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Come Together:
Firm Boundaries and Delegation*

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Abstract

We develop an incomplete-contracts model to jointly study firm boundaries and the allocation of decision rights within them. Integration has an option value: it gives firm owners authority to delegate or centralize decision rights, depending on who can best solve problems that may arise in the course of course of an uncertain production process. To examine the evidence, we construct measures of vertical integration and delegation for thousands of firms in different countries and industries. In line with the model's predictions, we find that input value and supplier uncertainty play a key role in shaping both integration and delegation choices.

JEL classifications: D2, L2.
Keywords: Integration, delegation, uncertainty, real options, supply assurance.

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1 Introduction

Why do firms integrate suppliers? One benefit, of course, is to have control over production decisions: in the presence of contracting frictions, ownership rights allow top management to improve productive efficiency by imposing costly investments on suppliers, such as conforming to standards, re-tooling, or even relocating their plants.

Equally important, if less appreciated, integration confers greater control over the firm's internal organization. Among the residual decision rights bundled with owning an asset is the ability to re-assign its use or control to others. Over the course of a lengthy and uncertain production process, different types of problems are bound to arise, and top managers may wish to re-allocate decision rights among themselves and their suppliers to solve them according to their relative expertise. Within a firm's boundaries, management can do this more or less seamlessly, choosing to delegate production decisions to its integrated suppliers or to centralize those decisions, depending on which problem arises. This option is hardly available outside the firm, where suppliers maintain control of their production decisions as part of their ownership rights. Firm boundaries and the allocation of decision-making inside the firm are thus intrinsically linked.

The "control over control" that comes with ownership helps guarantee the firm a minimum quality and quantity of inputs, and thereby introduces a novel mechanism of supply assurance as a rationale for integration: the advantage of ownership is not so much that it can be used to force a supplier to provide an input that he might otherwise sell to someone else, but that it allows the firm to deploy control to the party best suited to using it. This greater flexibility of integration compared to outsourcing has been cited as one of the reasons why Apple has recently decided to integrate the production of computer chips.[1]

Failure to appreciate the interdependence between the firm boundaries and the internal power structure can be disastrous, as Boeing's infamous 787 Dreamliner fiasco starkly illustrates. Boeing outsourced the design and manufacture of key components of the 787 (e.g., fuselage, wings, stabilizers) to independent suppliers. Unprecedented problems in design and compatibility ensued, often due to poor quality sub-components, which led to years of delivery delays and billions of dollars in cost overruns.[2]

[1]The decision, announced in June 2020 at the Apple's annual Worldwide Developers Conference, was partly driven by Apple's desire to "[give] itself more flexibility and agility when it comes to future products" (see "Apple Mac computers make jump to its own chips").

[2]In sharp contrast to Boeing's prior practice of providing all designs and performing intermediate as well as final assembly, the change of ownership structure left each major supplier with responsibility "for managing its own [sub-component] subcontractors," which "operated largely out of Boeing's view." Resulting delays ran to 40-months, and overruns to more than $10 billion. Part of Boeing's remedial reorganization for the Dreamliner was to acquire some of the major suppliers in order to have more direct control on the production of its inputs

Despite their evident connection, the interplay between vertical integration and delegation has scarcely been explored. This paper brings these twin organizational design decisions together, both theoretically and empirically. It first develops a model to jointly study vertical integration and delegation. It then assesses the evidence in light of the model, combining information on vertical integration and delegation for thousands of firms in multiple countries and industries.

The theoretical model considers the relationship between headquarters (HQ) producing a final good and each of her input suppliers. Firm boundaries and the internal allocation of control are endogenous, the result of optimizing behavior by these parties. The model is founded on a fundamental conceptual distinction between delegation and non-integration. Delegation is a non-contractible act of relinquishing control that can in principle be revoked at will by managerial fiat. Non-integration, by contrast, is defined by formal titles and requires legal intervention to reverse via an asset sale (Baker, Gibbons, and Murphy, 1999; Williamson, 2005).[3]

Each input has to be adapted to the specific needs of HQ, and this requires coordinated production decisions involving both HQ and each supplier. Complicating this process are two main sources of uncertainty. The first is standard quantity or quality risk that clouds inference about underlying decision variables, rendering them non-contractible. The second source is central to the organizational design and concerns problems that may arise during the course of production: at the time when HQ and the supplier decide whether to integrate, they do not know the exact production needs and associated challenges that they may encounter in the future.

HQ and the supplier diverge in several dimensions. First, they differ in their ability to solve the problems that may arise during the course of production: the supplier is better than HQ at some, worse than her at others, and organizational performance therefore depends on the assignment of control over problem solving.[4] Second, the supplier and HQ have conflicting preferences over production standards, possibly due to differences in training, background, corporate culture, or managerial vision.[5] And third, contracting frictions imply that the supplier has smaller residual stakes in the enterprise profit than HQ.

(see Tang and Zimmerman, 2009; Zhao and Xu, 2013; and McDonald and Kotha, 2015).

[3]Indeed, non-integration has legal force, while delegation does not. The law not only regulates and registers asset sales, it frequently adjudicates disputes between parties who hold separate titles. Once they are integrated, however, the parties largely forego appeal to the law in many of their disputes, and via the business judgment rule, are immune to its intervention in most matters, in particular who will make various business decisions.

[4]In this respect, our setup resembles Garicano (2000)'s model of the organization of knowledge in production, though the mechanism by which problem solving is assigned to parties is different, as discussed below.

[5]Tensions about the way operations should be carried out within firms are emphasized by Van den Steen (2005), Hart and Holmström (2010), among others.

Under integration, HQ owns the input production line and can therefore decide whether to solve problems and implement all production decisions (centralization) or instead to make the supplier in charge of problem solving as well as some — but not all — production decisions (delegation).[6] Since centralization puts decisions in the hands of one party, it tends to coordinate them well, but this comes at the expense of high private costs to the supplier as well as his forgone expertise. Because it is simply not feasible to put *every* decision in the hands of the supplier, delegation can take advantage of his competence, but at the cost of some coordination loss: the supplier chooses his preferred production standards, and HQ bears significant private cost to perfectly coordinate her residual decisions with his. Nevertheless, because of the ability to redeploy to the better decision maker as circumstance dictate, integration assures HQ of at least a minimal (expected) supply of the input.

By contrast, with non-integration, the supplier owns the line, so HQ has no option to centralize or delegate decision rights. Given his low residual stakes, the supplier avoids the private costs of doing things HQ's way by always choosing to retain control, even when the problems are those that HQ is better equipped to handle. Like delegation, non-integration suffers coordination losses, since it would be privately too costly for HQ to coordinate her decisions with the supplier's. What is more, supply of the input is less assured, since it depends on the supplier's competence, which may be low for some problems. But non-integration minimizes the costs of the supplier, who can always make production decisions in line with his preferences.

The model refines the "value principle" that emphasizes the role of pecuniary variables such as profitability and prices in the organizational design calculus, and extends it beyond the integration context where it has already been applied (Legros and Newman, 2013, 2017). The flexibility to reassign control makes integration into a kind of real option.[7] Thus, the option value of integration needs to be considered when ownership decisions are made.[8] Moreover, input value affects not only which suppliers HQ integrates, but also whether she delegates to subordinate suppliers or retains control over their production decisions.

In particular, the model predicts that suppliers that contribute more to enterprise value should be more likely to be integrated; and within firm boundaries, top management should

[6]An alternative mechanism for allocating control would be a contract that specifies for any contingency who makes each decision. In practice, verifying the identity of a decision maker, and of the circumstances in which she allegedly made a decision, appears to be very costly, and therefore the scope of such contracts is limited. We set them aside in our main analysis; see Section 3.2.2 (esp. Remark 3) for further discussion.

[7]More precisely, acquiring the supplier creates one option (HQ's), while destroying another (the supplier's), though as mentioned, in equilibrium a supplier that remains non-integrated never chooses to exercise the option, while HQ does.

[8]See Dixit and Pindyck (1994) for a general discussion of investment decisions under uncertainty in a real options framework.

be more likely to delegate decisions to suppliers of more valuable inputs. The integration result occurs because the return to having an assured supply of an input increases when the input is more valuable, and it is therefore more likely to offset the supplier's private cost. The delegation result stems from the greater weight parties place on the common profit interest than than on their private costs as value increases: HQ is less reluctant to delegate to a supplier when she is more confident that decisions will be aligned with the organization's interest.

We also consider how uncertainty in the ability of suppliers to solve problems that may arise during production affects the organizational decisions. We show that first-order shifts in the productivity distribution of suppliers imply more delegation among integrated suppliers because that means they are more likely to exceed the capability of HQ. And because of the convexity in the option value of integration, the model also suggests that the expected return to HQ of integration must increase with the degree of risk about production problems. Risk has also an ambiguous effect on the expected private cost the supplier will have to bear (i.e., whenever HQ decides to centralize), and therefore on the cost of integration, but the net effect favors integration for distributions close to lognormal, which our data approximate.

To assess the evidence, we combine information from the WorldBase dataset by Dun & Bradstreet and the World Management Survey (WMS), which allows us to measure integration and delegation choices for firms in 20 countries. To measure input value, we use disaggregated input-output data from the US Bureau of Economic Analysis (BEA). To proxy for the riskiness of an input industry, we use different measures of the dispersion in the performance of suppliers in that industry.

The evidence confirms the role of input value for integration and delegation choices, in line with our theoretical model. We find that final good producers are indeed more likely to integrate suppliers of more valuable inputs. Among integrated suppliers, more autonomy is granted to those producing more valuable inputs. In terms of magnitude, our estimates indicate that increasing the input-output coefficient by one standard deviation increases the probability of integration by 0.6 percentage points (which corresponds to a 60 percent increase given the baseline probability of one percentage point) and increases delegation by around 0.05 standard deviations.

Also consistent with the theoretical model, we find that delegation increases with the mean productivity in the input industry. Specifically, a one-standard-deviation increase in the mean raises delegation by around 0.032 standard deviations. Moreover, the probability that firms integrate a particular input increases with the riskiness of the input industry. In terms of magnitude, a one-standard-deviation increase in our preferred measure of input risk increases the probability of integrating a supplier by around 0.34 percentage points (which corresponds to a 34% increase relative to the baseline integration probability).

The empirical results of our baseline regressions hold up in a series of robustness checks, e.g., using different samples of firms, including plant-level and firm-level controls, input-industry and output-industry fixed effects. In the integration regressions, we can also include firm fixed effects, exploiting variation within firms across input industries (in the riskiness of the industry or the value of the input) to identify the role of input value and input risk.

We see our contribution as a benchmark for understanding how elements of organizational design that were previously considered separately may fit together in theory and practice. By combining delegation and firm boundary choices in a unified framework, our analysis suggests that the right to allocate control that is acquired with asset ownership renders integration into a real option that could help firms to cope with supply-chain risk. Analysis like this is essential for understanding how firms may reorganize in a world of growing uncertainty (Altig *et al.* 2020), as well as what optimal policy responses might be.

The structure of the paper is as follows. Section 2 briefly reviews the related literature. Section 3 presents the theoretical model. Section 4 describes the data and variables used in the empirical analysis. Section 5 presents the empirical results. Section 6 offers some concluding comments about the implications of our findings for the theory of the firm.

2 Related Literature

Organizational economists generally agree that the diverse elements of organizational design interact with each other and must work in concert for optimal performance (Milgrom and Roberts, 1990; Roberts, 2007). Yet, the economics of firm organization itself is starkly split into separate divisions (Gibbons and Roberts, 2013). There are theories of what determines the boundaries of the firm. Then there are theories of how a firm organizes itself internally, for example in the degree to which decisions are delegated from top- to mid-level managers.

Although some studies have emphasized the conceptual difference between integration and delegation (Baker, Gibbons, and Murphy, 1999; Hart and Holmström, 2010), there has been little theoretical work to operationalize these differences. And, to the best of our knowledge, there is no systematic empirical work along those lines. Understanding the functioning of complex organizations has become even more important in light of recent studies emphasizing how organization affects aggregate and firm-level performance (e.g., Hortaçsu and Syverson, 2007; Forbes and Lederman, 2010; Bloom, Sadun, and Van Reenen, 2016; Akcigit, Alp, and Peters, 2018).

Our work is mainly related to two streams of literature, which focus on each of the organizational choices we bring together in this paper. First, we build on the vast literature on firm boundaries. Theoretical studies have looked at inter alia the technological/contractual determinants of vertical integration (e.g., Coase, 1937; Grossman and Hart, 1986; Hart and Moore, 1990; Holmström and Milgrom, 1991; Hart and Holmström, 2010). The view of integration in our model is similar to that of Williamson (1975), and puts it in the "ex-post non-contractible" branch of incomplete-contracts economics (e.g., the 2002 version of Hart and Holmström, 2010; Aghion, Dewatripont, and Rey, 2002; Legros and Newman, 2008; Dessein, 2014). Another strand has focused on market determinants (e.g., McLaren, 2000; Grossman and Helpman, 2002; Legros and Newman, 2013; Conconi, Legros, and Newman, 2012). Earlier theoretical approaches include the resource-based view of Wernerfelt (1984), the routines-based theory of Nelson and Winter (1982), and the knowledge-based explanation of Kogut and Zander (1992).

Lafontaine and Slade (2007, 2013) provide an excellent overview of the empirical literature on firm boundaries. Some studies have tried to shed light on the determinants of vertical integration using firm-level data within specific industries (e.g., Joskow, 1987; Woodruff, 2002; Baker and Hubbard, 2003), countries (e.g., Acemoglu *et al.*, 2010), or across industries within countries (e.g., Acemoglu, Johnson, and Mitton, 2009), In addition to exploring the determinants of firm boundaries, the literature has examined the consequences of vertical integration. For example, Chipty (2001), Hortaçsu and Syverson (2007), and Forbes and Lederman (2010) study the impact on production efficiency and competition (respectively in the cable TV, ready-mix concrete, and airline industries).

Theoretical studies in the delegation literature include Holmström (1984), Aghion and Tirole (1997), Dessein (2002), Hart and Moore (2005), Alonso, Dessein, and Matouschek (2008), Alonso and Matouschek (2008), Marin and Verdier (2008), Dessein, Garicano, and Gertner (2010). Much (but by no means all) of this literature views delegation as a means of achieving better outcomes by assigning decision rights to (ex-ante) better informed parties; often this helps to incentivize delegates to become more informed in the first place. In our simplified model of delegation, the assignment of control is instead a *response* to (symmetric) information: the (ex-post) sufficiently more capable (or possibly less time constrained) party gets it. The two approaches are complementary — the production decisions could involve the acquisition of further information — and our approach is mainly for tractability. On the empirical side, contributions include Acemoglu *et al.* (2007), Guadalupe and Wulf (2010), McElheran (2014), Caliendo, Monte, and Rossi-Hansberg (2015), Wu (2017), and Katayama, Meagher, and Wait (2018).

A number of papers have studied pairwise interactions of organizational design elements from the theoretical point of view. Examples include Holmström and Tirole (1991), Holmström and Milgrom (1991, 1994), Dessein, Garicano, and Gertner (2010), Rantakari (2013), Friebel and Raith (2010), Van den Steen (2010), Dessein (2014), and Powell (2015). As far as we are aware, only Baker Gibbons, and Murphy (1999) and Hart and Holmström (2010) consider delegation and firm boundaries together, and only from a theoretical perspective.

As to the particular modeling elements we employ, our approach to delegation is closely related to work on the design of knowledge hierarchies (Garicano, 2000) and referrals (Garicano and Santos, 2004) insofar as we are concerned with allocation of decision making among the organization's members according to the expertise at solving particular production problems. In those papers the allocation of control is decided contingently through contracts rather than managerial authority, and they abstract from incentive problems, which play a key role in the comparative statics of our model. Moreover, they endogenize knowledge acquisition, while we take competence as given.

Our finding that suppliers of inputs that contribute more value to the production of a firm's output, as proxied by input-output coefficients, are more likely to be integrated is in line with the results of previous studies on firm boundaries (e.g., Alfaro *et al.*, 2019; Berlingieri, Pisch, and Steinwender, 2020). In this paper, we show theoretically and empirically that input value also affects delegation choices within the firm boundaries: top management delegates more decisions to suppliers of more valuable inputs.

Finally, our paper is related to the literature on supply assurance motives for integration (e.g., Carlton, 1979; Bolton and Whinston, 1993; Baker, Gibbons, and Murphy, 2002). Those papers tend to focus on demand uncertainty and the ability of non-integrated suppliers to sell their inputs to other buyers. The supply assurance in our model derives from uncertainty about the production process, or more precisely, the capabilities of the firm's members to solve attendant problems.

3 The Model

3.1 Production

Consider a production process in which a final good j is produced with n inputs indexed by i. An enterprise is composed of an HQ, who produces the final good, and n suppliers, S_i, each comprising a manager$_i$ (who will usually be referred to as a supplier) and an indivisible productive asset that can be owned by manager$_i$ or HQ. All players are risk neutral. The expected value of a good produced by the enterprise can be written as

$$P_j \sum_{i=1}^{n} \pi_{i,j} \, \mathbb{E}V_{i,j}, \tag{1}$$

where P_j is the price of the final good and $\pi_{i,j}\ \mathbb{E}V_{i,j}$ is the contribution of each supplier i.[9] This is decomposable into an exogenous, technologically dictated value-added share $\pi_{i,j}$ and an endogenous quantity $\mathbb{E}V_{i,j}$ that will be shaped by production and organizational decisions made by HQ and supplier i. For now, we consider the relationship between HQ and a typical supplier and suppress the index notation; we also normalize $P_j = 1$.

There are two sorts of uncertainty in this model. One is the standard contract-theoretic quantity or quality uncertainty that renders many decisions non-contractible. The second is more specific to the organizational design concerns in this paper, which is uncertainty over which specific problems will arise in the course of production — and therefore who is best suited to to tackle them — that drives the delegation decision and is the source of the option value of integration.

3.1.1 Technology

Production of the input proceeds in two stages: the first generates a basic input, and involves the active participation of the supplier. The second is the adaptation stage and is carried out by the HQ alone. Examples of these two stages might be part production and general assembly, or manufacturing and marketing. We represent the possible choices by $s \in [0, 1]$ for the first stage, $h \in [0, 1]$ for the second. The main difference between s and h is that, while s can be decided by either party, h always remains with HQ. It is worth emphasizing that no matter who makes the decisions, the cost of s is borne by the supplier and the cost of h is borne by HQ.

Decisions affecting input characteristics made at each stage — design, materials, style, brand adherence, even attitudes or employee culture — need to be coordinated to ensure maximal value. Successful production of the input depends on first-stage and second-stage decisions: a unit of input is successfully adapted to HQ's needs (yields the return π) with probability $p(|s - h|)$ and fails (yields zero) otherwise. Assume that $p(\cdot)$ is decreasing, concave, and differentiable, with $p(0) = 1$ (for instance, $p(|s - h|) = 1 - (s - h)^2$). Thus, the generated value of inputs depends not so much on the magnitudes of s and h as on the gap between them.[10]

The obstacle to perfect coordination is that HQ and the supplier have opposite preferences on how to carry out basic input production and find it costly to accommodate the other's

[9] The model can be easily extended to allow for heterogeneity in value across firms within the same output industry, if for example different HQs have different entrepreneurial ability.

[10] This specification provides a simple way to capture coordination problems within firms and is common in the organizations literature (e.g., Dessein and Santos, 2006; Alonso, Dessein, and Matouschek, 2008; Legros and Newman, 2013).

approach. This could be due to differences in background, technologies, or "vision," possibly arising from the fact that they are in different industries.[11] Specifically, HQ has private cost $d(h)$ per unit of input, while the supplier has private cost $c(1-s)$, where the costs $c(\cdot)$ and $d(\cdot)$ have standard properties: $c(0) = d(0) = 0$, they are differentiable on [0,1], strictly increasing and convex, and satisfy the Inada conditions. Hence, HQ prefers the production standards s to be close to 0, while the supplier likes them close to 1.

The quantity uncertainty mentioned above is manifested in two ways: both the number of usable basic inputs that the supplier can deliver after the first stage, and the success of the HQ's own production decision in adapting usable inputs in the second stage are non-verifiable, making it impossible to write contracts contingent on these outcomes.[12] In turn, this limits the means by which control can be allocated and plays a role in the determination of transfer prices between the supplier and HQ.

In addition, HQ and the supplier are uncertain about the various possible challenges that may arise in the course of input production, and have different expertise in overcoming them. This source of uncertainty is modeled by a set $\theta \in [0, 1]$ of potential "problems" (or opportunities) that affect the basic stage of production. These can be interpreted broadly: examples might be new designs for the input, quality control or compatibility issues, disruptions further up the supply chain, or having to replace a key employee. Problems arise according to an absolutely continuous distribution $F(\theta)$.

The choice of standard s and the solution to the problem are linked: either HQ or the supplier can address the problem, but whoever does must select s in the course of doing so. If HQ controls this process, z expected units of usable inputs are generated; if the supplier is in charge, the expected productivity is instead $y(\theta)$. Assume $y(\cdot)$ is strictly increasing (i.e., just label the problems in increasing order of the supplier's competence at solving them). $F(\theta)$ then induces an absolutely continuous distribution $G(\hat{y}) := F(y^{-1}(\hat{y}))$ over quantities $\hat{y}$.

HQ is a generalist, equally adept at addressing all problems (this can be relaxed), while the supplier is a specialist, better than HQ at solving at solving some problems, worse at solving others: $y(0) < z \leq y(1)$.[13] We assume that HQ is on average better at solving problems than the supplier:

$$\mathbb{E}y < z.$$

(from here on, unspecified expectations are with respect to the productivity distribution G).

[11]See Hart and Holmström (2010) for further discussion of production standards and private costs for organizational design.

[12]Even if the HQ's aggregate profits are verifiable, the supplier's contribution to them is too small to form the basis for meaningful incentives.

[13]The problem-arrival setup is similar to that in Garicano (2000), but the capability function $y(\theta)$ has a continuous range rather being binary-valued; other differences have already been discussed in Section 2.

Her competence z, as well as the supplier's competence function $y(\cdot)$ are common knowledge; each party knows exactly how well the other would perform in any given situation θ; there is only uncertainty as to which situation will arise, as represented by the distribution $F(\theta)$ and corresponding productivity distribution $G(y)$.

3.1.2 Contracting

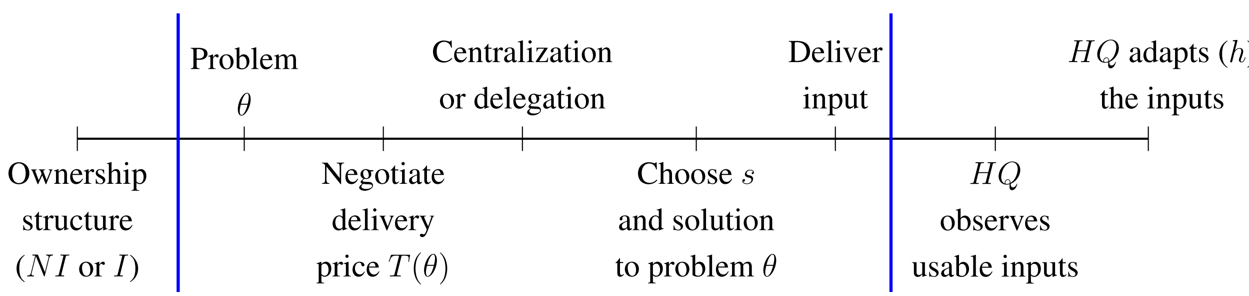
Contracting is limited to transfers of ownership and monetary payments for delivery of a batch of basic inputs. Nothing else is contractible, including the identity of decision makers/problem solvers, the usability (and therefore the number delivered) of inputs after the first production stage, the decisions s and h, or whether the input was successfully adapted. The supplier and HQ negotiate a fixed transfer for the batch (modeled with Nash bargaining), possibly dependent on θ, and payable upon delivery.

When negotiating ownership, the supplier and HQ take account of the expected costs that will ensue. We assume that both parties have sufficient cash at the time of ownership contracting to make any side payments needed to settle the distribution of surplus required to strike a deal. Thus we will be considering "efficient" ownership choices in what follows.

3.1.3 Timing

The sequence of events is illustrated in Figure 1.

Figure 1: Timing of Events



There are three main phases for each input used in the production of the final output (delineated by the blue lines in the figure).

(1) Ownership choice.

- HQ and the supplier decide on the ownership structure. The owner (the supplier if non-integration, HQ if integration) has the right to make decisions during the input production stage or to delegate them to someone else.

(2) Input production.

- The two parties learn problem θ and Nash bargain over the monetary transfer $T(\theta)$ for the delivery of input.
- The owner chooses whether to make the productive decisions (problem solution and standard s) or to delegate them to the other party.
- A batch of inputs is produced and delivered to HQ.

(3) Adaptation.

- HQ learns the number of usable inputs (on average $y(\theta)$ if the supplier made the decision or z if HQ made the decision), and chooses the adaptation effort h for each usable unit in the batch.
- Usable inputs are adapted with probability $p(|s-h|)$.

To summarize, the surplus is $[\mathbb{H}z+(1-\mathbb{H})y(\theta)][\pi p(|s-h|)-d(h)]-c(1-s)$, where $\mathbb{H}$ is an indicator whether HQ controls the production standard s and the problem solution, $p(|s-h|)$ is the probability of successful adaptation, and $d(\cdot)$ and $c(\cdot)$ are HQ's and the supplier's private costs.[14] Of course, the production choices s and h are affected by the governance structure (which includes the choice of $\mathbb{H}$, the purview of the asset's owner), as we now describe.

3.2 Input Value and Organizational Design

Suppose that problem θ arose and HQ has received the $y(\theta)$ usable units of input from the supplier. The transfer $T(\theta)$ for the batch is then sunk, so HQ chooses h to maximize the continuation payoff $y(\theta)[\pi p(|\hat{s}-h|)-d(h)]$, where $\hat{s}$ is the supplier's equilibrium choice of the production standard.

3.2.1 Non-Integration

As the supplier owns the input before agreement to delivery, his Nash bargaining disagreement payoff is some generic market value P_0 times the quantity he expects to produce $y(\theta)$, while HQ's is zero, since she would have to do without the input in case of disagreement. As

[14] The expression reflects that HQ only incurs a cost on each unit she discovers to be usable during the adaptation stage. The supplier's cost is effectively fixed — for instance the cost of adopting a new method — or could be thought of as proportional to the size of a batch of rough inputs, which in turn is independent of θ or the identity of the problem solver. Other specifications of supplier costs would yield similar results.

s is not contractible, the payment from HQ to the supplier cannot depend on it. The supplier incurs expected cost $c(1-s)$ and therefore chooses s to solve $\max_s T(\theta) - c(1-s)$, resulting in a choice $s^N \equiv 1$ and cost $c(0) = 0$.[15]

HQ, knowing the equilibrium value of s to be $s^N = 1$, generates continuation value $y(\theta)v(\pi)$ where $v(\pi) \equiv \max_h[\pi p(|1-h|) - d(h)]$ (our assumptions on $d(h)$ ensure the existence of an interior solution h^N to HQ's problem). Note that $v(\pi)$ is increasing and convex with $v(0) = 0$: by the envelope theorem $v'(\pi) = p(|1-h^N|)$; this is increasing by standard monotone comparative statics arguments, which imply that h^N, and therefore $p(|1-h^N|)$ increase with π.

The (symmetric) Nash bargaining transfer $T(\theta)$ for the batch of input is equal to half of the continuation value $v(\pi)y(\theta)$plus half of $P_0 y(\theta)$; thus the supplier's sales are

$$y(\theta)(v(\pi) + P_0)/2. \tag{2}$$

At the time of the ownership decision, non-integration yields an expected surplus of

$$v(\pi) \cdot \mathbb{E}y.$$

3.2.2 Integration and the Delegation Decision

When HQ owns the supplier's asset, since she already controls the produced input, her disagreement payoff is simply the continuation surplus $[\mathbb{H}z + (1-\mathbb{H})y(\theta)[\pi p(|\hat{s} - h|) - d(h)]$, while the supplier's is zero. We use this observation to asses the delegation decision within the integrated relationship.

HQ can choose to centralize, retaining control of s, in which case she ignores the supplier's cost and solves

$$\max_{h,s} z[\pi p(|s-h|) - d(h)],$$

resulting in the solution $h^C = s^C = 0$. Her monetary payoff is equal to $z\pi$, while the supplier incurs the private cost $\overline{c} \equiv c(1)$.

Alternatively, HQ can delegate, letting the supplier control the production-and-problem-solving process. Anticipating the delivery transfer of zero (more generally, one that does not

[15]Since the non-integrated supplier receives a fixed transfer $T(\theta)$ upon delivery, he has no incentive to delegate to HQ; if he did, anticipating her choice of $s < 1$, he would receive the same payment but incur the higher cost $c(1-s) > 0$. While delegation may be surplus enhancing for low values of θ, the supplier cannot commit not to interfere and, contrary to usual principal-agent settings, there is no verifiable output that can serve as a basis for inducing S to delegate to HQ (contracting directly on the control allocation has already been ruled out). By contrast, because HQ is the full residual claimant on the value of adapted inputs, she internalizes the benefits of delegating to S under integration.

depend on the continuation value), the supplier will choose his least-cost standard $s^D = 1$, in which case HQ's maximized expected surplus is the same as under non-integration, namely $\max_h y(\theta)[\pi p(|1-h|) - d(h)] = y(\theta)v(\pi)$, and her choice is $h^D = h^N$. HQ therefore delegates when $\pi z < v(\pi)y(\theta)$, or $y(\theta) > y^*(\pi) := z\frac{\pi}{v(\pi)}$. From the convexity of $v(\pi)$, $\frac{\pi}{v(\pi)}$, and therefore the cutoff value $y^*(\pi)$, are decreasing functions of π. It follows that

Result 1. *The probability $1-G(y^*(\pi))$ that HQ delegates a decision to an integrated supplier is increasing in the value of the input produced by the supplier.*

This result is driven by HQ's improving incentives (increasing willingness to sacrifice private benefits for profit) as the value of the HQ-supplier relationship increases. Were it not for the incentive problem, HQ would delegate whenever the supplier's competence on a problem exceeded her own, but here $y^*(\pi)$ strictly exceeds z by the factor $\frac{\pi}{v(\pi)}$ to take account of "incentive wedge." Higher values of π reduce that wedge, as HQ increasingly sets aside her privates costs in favor of profit.[16]

Remark 1. It has long been argued (Coase, 1937) that managerial authority under integration can lead to various kinds of rigidities. How does this square with integration's flexibility, particularly with respect to organizational design, that is being emphasized here? In the present model, *centralized* decisions are indeed rigid: $h = s = 0$ independent of any parameter. However, this is not the case for h under delegation, which varies with the parameter π; for the decision whether to delegate in the first place, which depends on θ; or for s, which varies with the governance structure. In light of the model, it may thus be more accurate to say that it is centralization, rather than integration *per se* that is rigid.

Remark 2. Delegation (or decentralization within firms) is often associated with better performance, i.e., higher generated value, and some theories suggest that causality runs from delegation to value, for instance because it improves incentives or morale. In this model, causality runs in the opposite direction, from value generated to delegation, for two reasons: an incentive effect (higher value contributions, as captured by π, improve incentives, making HQ more willing to delegate); and a selection effect (delegation is only chosen when the supplier is relatively more competent).

Remark 3. In this model, the informal allocation of decision making afforded by integration implies that HQ ignores the costs she imposes on the supplier when she centralizes control. Contrast this situation with one in which some mechanism, formal or otherwise,

[16]This result does not depend on the constancy of z, which could instead be any measurable function $z(\theta)$, provided neither $y(\cdot)$ nor $z(\cdot)$ dominates the other. For if $y(\theta) > \frac{\pi}{v(\pi)}z(\theta)$, then $y(\theta) > \frac{\pi'}{v(\pi')}z(\theta)$ for $\pi' > \pi$, because $\frac{\pi}{v(\pi)}$ is decreasing. Thus the measure of problems that will be delegated to the supplier is non-decreasing in π.

exists to take account of both parties' costs in allocating control. In this case of "efficient decentralization," the supplier gets control when $v(\pi)y(\theta) > z\pi - \overline{c}$. For low levels of π, this is true for all θ: HQ's authority imposes fixed costs on subordinates, and incurring them when the value return is very low is inefficient, since the profit gain from centralizing could never be large enough to offset the fixed cost. As the value increases, it becomes worthwhile to centralize the decision making on the problems at which the supplier is most inept, because that is where the profit gains are largest; as value increases further, the profit gains to centralizing become worth the fixed costs for larger sets of problems. Thus, efficient decentralization would be *falling* with π, at least in a range where π is small. As π increases further, the incentive-wedge effects discussed above may come to dominate, leading to a *non-monotonic* (U-shaped) response of efficient decentralization to value.[17] Our data display no evidence of either possibility.[18]

3.2.3 The Firm Boundary Decision

Since integration is decided before production begins, expectations with respect to problems θ must be used to determine optimal ownership choices. The expected value of integration is $\mathbb{E}\max\{\pi z, v(\pi)y\} - \overline{c}G(y^*(\pi))$, while the expected value of non-integration is $v(\pi) \cdot \mathbb{E}y$. Integration occurs when its expected value exceeds that of non-integration:

$$\mathbb{E}\max\{\pi z - v(\pi)y, 0\} > \overline{c}G(y^*(\pi)). \tag{3}$$

The right-hand side of this "put-option" condition is decreasing with π by Result 1. Meanwhile the left-hand side is increasing in π.[19] We can thus state the following:

Result 2. *If there is integration at π, there is integration at $\pi' > \pi$.*

[17] Formally, efficient decentralization occurs when

$$y(\theta) > \frac{z\pi - \overline{c}}{v(\pi)};$$

for $\pi \leq \overline{c}/z$ the right hand side of this expression is non-positive, so it is efficient to decentralize for all θ there. Decentralization is then decreasing in π if the right-hand side is increasing, i.e., if $1 > (\pi - \overline{c}/z)\frac{v'}{v}$, which is clearly true for π in a right neighborhood of $\overline{c}/z$. This could remain true for all π, or, if eventually $1 < (\pi - \overline{c}/z)\frac{v'}{v}$, efficient decentralization would be non-monotonic.

[18] To be sure, the firm is unlikely to integrate at low levels of π (see below), so complete decentralization is accomplished via non-integration. But this is a blunt instrument: as soon as integration starts to happen, there is too little decentralization.

[19] The derivative of the left hand side, using $z\pi = v(\pi)y^*(\pi)$, is

$$\left[z - v'(\pi)\mathbb{E}\{y|y < y^*(\pi))\}\right] \cdot G(y^*(\pi)),$$

which is positive because $v'(\pi)\mathbb{E}\{y|y < y^*(\pi)\} \leq v'(\pi)\mathbb{E}y < v'(\pi)z = p(1 - h^N)z \leq z$.

In other words, the likelihood that a supplier is integrated grows with the input's contribution to total firm value. This result is similar to the one in Legros and Newman (2013) (with the value-added parameter π standing in for the market price used there), though in that model, the possibility of delegation is not considered (indeed, one could think of that model as a special case of this one in which $y(\theta)$ never exceeds z).

Looking back at the expression (1) for the expected value of an enterprise, Results 1 and 2 imply that the suppliers with higher input value ($\pi_{i,j}$) are the ones most likely to be integrated and, among those that are, to have higher degrees of delegation.

Other sources of variation in enterprise value would have similar effects. For instance, if the output price P_j, (which we have so far set equal to 1) were to vary across different industries, then πP_j would replace π in all the formal expressions above; HQs in high-value industries would have higher propensities to integrate their suppliers and to delegate to them than would HQs in low-value industries.[20]

We could also allow value to vary across firms within an industry, e.g., if their HQs have different entrepreneurial ability. The effects of this variation on integration and delegation choices would be similar to those of input value and output prices: both the propensity to integrate suppliers within the firm boundaries and the propensity to delegate decisions to integrated suppliers would increase in HQ's ability.

These simple extensions of our model imply that integration and delegation should covary positively: more valuable firms (e.g., those that can sell their products at higher prices, or have more capable HQs) should integrate more suppliers and grant more autonomy to them.

3.3 Uncertainty and Organizational Design

As has been noted elsewhere (Hart and Holmström, 2010), and as the present model illustrates, uncertainty plays an essential role in delegation choices. If the parties could perfectly anticipate θ at the time of the integration decision, there would never be a strict incentive to integrate and subsequently delegate: either $y(\theta)v(\pi) \leq z\pi - \overline{c}$, in which case there will be integration with centralization, or $y(\theta)v(\pi) > z\pi - \overline{c}$, in which case non-integration performs at least as well as integration, strictly so if $z\pi > y(\theta)v(\pi)$ (for then HQ would centralize) or if the acquisition of the supplier's asset has even infinitesimal cost. Contrary to the data, no variation in the degree of integrated supplier autonomy would be observed, as no HQ would delegate at all. And as we have already discussed, the ability to hedge against uncertainty via centralization affects the value of owning assets.

To be more precise about how uncertainty affects delegation and integration, we consider

[20] Evidence for this effect can be found in Alfaro *et al.* (2016), and McGowan (2017).

the comparative statics of (first-order) stochastic dominance and of risk (in the Rothschild-Stiglitz sense) in the distribution $G(y)$.[21]

3.3.1 Delegation

The degree of delegation is equal to $1-G(y^*(\pi))$, the probability that y exceeds the threshold $y^*(\pi)$. From the definition of stochastic dominance the following is immediate as well as intuitive:

Result 3. *Stochastic increases in the supplier productivity distribution $G(y)$ lead to a higher probability of delegation.*

When problems are more likely to land in the supplier's sphere of competence, it is more likely that he will be the one asked to solve them.

However, because the cumulative probability at any given y value — $y^*(\pi)$ in particular — can increase or decrease with increases in risk (indeed it must: risk-comparable c.d.f.'s cross at least once), there is no general prediction about the effects of risk on delegation: increasing risk tends to fatten both upper and lower tails, so the supplier is roughly as likely to be more as less competent than before, yielding a correspondingly ambiguous change in HQ's willingness to delegate.

3.3.2 Integration

The integrand $\max\{\pi z - v(\pi)y, 0\}$ from put-option condition (3) is decreasing and convex in y. So the relative value of integration over non-integration is decreasing with stochastic increases in $G(y)$: the more likely the supplier will be the one better capable at solving problems, the less valuable is the option to centralize, and with that, the lower is the value of integration. The cost of integration (proportional to the likelihood of centralization) decreases as well, however, so the net effect on integration appears to be difficult to determine without more specific information about the distributions.

As would be expected from the theory of options, where more uncertainty increases option value, more risk in the supplier's capacity to solve problems raises the value of integration. But again, the cost of integration $\bar{c}G(y^*(\pi))$, could rise or fall with increases in risk. Despite this ambiguity, the effects on integration of changes in the riskiness of $G(y)$ can be signed for certain classes of distributions, in particular the lognormal family, which is salient

[21] A distribution $\hat{G}$ is stochastically larger than G if $\hat{G}(y) \leq G(y)$ everywhere, with strict inequality on a non-null set. $\hat{G}$ is riskier than G if the two distributions have the same mean and $\int^x \hat{G}(y)dy \geq \int^x G(y)dy$ for all x, with strict inequality on a non-null set.

for our empirical analysis. Within that class, the relative benefit effect dominates the cost effect, even if it happens to be countervailing, so we have:

Result 4. *If there is integration at lognormal* $G(y)$, *there is integration at a riskier lognormal* $\hat{G}(y)$.

For the proof of this result, see the Theoretical Appendix.

3.4 Testable Implications

According to the theoretical model (Results 1 and 2), both integration and delegation choices should depend on input value. Suppliers of more valuable inputs should be more likely to be integrated with firms; among the integrated suppliers, those producing more valuable inputs should be delegated more decisions. These results lead to the following testable predictions, which we will bring to the data in Section 5.1:

> **P.1**: Firms should be more likely to delegate production decisions to integrated suppliers that produce more valuable inputs.
>
> **P.2**: Firms should be more likely to integrate suppliers that produce more valuable inputs.

The model also suggests that delegation and integration choices should depend on characteristics of the distribution $G_i(y)$ in each input industry i. For a large number of ex-ante identical suppliers, observed differences in productivity can be attributed to different production problems θ having arisen for each supplier. In our empirical analysis, we will measure $G_i(y)$ with the distribution of labor productivity (sales/worker) of independent suppliers in an input industry i (recall from expression (2) in Section 3.2, supplier sales are proportional to $y(\theta)$, so sales and employment data can serve as proxies for productivity in the model). As shown in Figure A-3 in the Empirical Appendix, this distribution approximates a lognormal distribution.

In addition to validating the hypothesis of Result 4, lognormality allows for simple parametric measurement of stochastic dominance and risk in terms of the mean and coefficient of variation (see Levy, 1973), which will be employed in the empirical analysis. In particular, controlling for the coefficient of variation, differences in the mean productivity of suppliers in input industries proxies for first-order stochastic differences in $G_i(y)$. Moreover, controlling for the mean, differences in the coefficient of variation proxy for differences in Rothschild-Stiglitz risk.

In Section 5.2, we will assess the validity of the following predictions that correspond to the theoretical Results 3 and 4:

P.3: Firms should be more likely to delegate to their integrated suppliers that operate in stochastically more productive input industries.

P.4: Firms should be more likely to integrate suppliers that operate in riskier input industries.

4 Data and Variables

4.1 Datasets

In what follows, we describe the datasets used in our empirical analysis to construct firm-level integration and delegation measures and to assess the role of input value and uncertainty in shaping these decisions.

WorldBase

The first dataset used in the empirical analysis is WorldBase, which provides coverage of public and private firms in more than 200 countries and territories.[22]

The WorldBase dataset has been used extensively in the empirical literature on firm boundaries (e.g., Acemoglu, Johnson, and Mitton, 2009; Alfaro *et al.*, 2019). The unit of observation in the dataset is the establishment/plant, namely a single physical location where industrial operations or services are performed or business is conducted. Each establishment in WorldBase is identified by a unique nine-digit sequence called Data Universal Numbering System (DUNS) number. For each establishment, WorldBase provides:

- Industry information: the 4-digit SIC code of the primary industry in which each establishment operates, and the SIC codes of up to five secondary industries.
- Ownership information: information about the firms' family members (number of family members, domestic parent and global parent).[23]

[22]WorldBase is the core database with which D&B populates its commercial data products that provide information about the "activities, decision makers, finances, operations and markets" of the clients' potential customers, competitors, and suppliers. The dataset is not publicly available but was released to us by Dun and Bradstreet. The sample was restricted to plants for which primary SIC code information and employment were available (due to cost considerations). For more information see: http://www.dnb.com/us/about/db_database/dnbinfoquality.html.

[23]D&B also provides information about the firm's status (joint-venture, corporation, partnership) and its position in the hierarchy (branch, division, headquarters).

- Additional information: location (country) of each plant, sales, employment, age.

WorldBase allows us to trace ownership linkages between establishments. In particular, we can use DUNS numbers to link all plants that have the same domestic or global parent. D&B defines a parent as a corporation that owns more than 50 percent of another corporation. To construct firm-level variables, we link all plants that have the same domestic ultimate owner, as in Alfaro *et al.* (2016).[24]

We use the 2005 WorldBase dataset and focus on the 20 countries that are also included in the World Management Survey described below. WorldBase contains 17,371,146 plants (corresponding to 16,718,199 parent firms). Median plant employment is 2, the mean is 288, and the standard deviation is 5,428 (see row "WorldBase dataset" in Table A-1).

World Management Survey

The World Management Survey (WMS) is a large scale project aimed at collecting high quality data on organizational design of firms around the world and has been used in many studies (e.g., Bloom, Sadun, and Van Reenen, 2012).

The survey is conducted through phone interviews with plant managers. Several features of the survey design are meant to guarantee the quality of the data. First, the survey is "double blind", i.e. managers do not know they are being scored and interviewers do not know the plant's performance.[25] This enables scoring to be based on the interviewer's evaluation of the firm's actual organizational practices, rather than their aspirations, the manager's perceptions, or the interviewer's impressions. Second, each interviewer ran 85 interviews on average. This allows to include interviewer fixed effects, which help to address concerns over the reliability and consistency of the answers. Third, information on the interview process itself (duration, day-of-the-week), and on the manager (seniority, job tenure and location) was collected. These survey metrics are used as "noise controls" to help reduce measurement error.

The main wave of interviews was run in the summer of 2006, followed by smaller waves in 2009 and 2010.[26] The survey achieved a 45% response rate, which is very high for company surveys.[27] Overall, the WMS contains around 11,691 plants in 20 countries. The sam-

[24] A "Domestic Ultimate" is a subsidiary within the global family tree which is the highest ranking member within a specific country and is identified by a "domuduns"' code. A "Global Ultimate" is the top most responsible entity within the global family tree and is identified by "gluduns" code. The two codes only differ in the case of multinationals firms.

[25] This was achieved by providing only firm names and contact details to the interviewers (but no financial details).

[26] A minority of the plants (668) have been interviewed in more than one wave of the WMS. The sample excludes plants where the CEO and the plant manager were the same person (only 4.9% of the interviews).

[27] The high success rate is due to the fact that (i) the interview did not discuss firm's finances, (ii) there were

pling frame was drawn to be representative of medium sized manufacturing firms in each country: median plant employment is 150, mean plant employment is 277, with a standard deviation of 405 (see row "WMS dataset" in Table A-1).

For each firm, only one (randomly selected) plant is surveyed in the WMS. Thus, we do not observe variation in delegation across plants belonging to the same firm. In a few cases, the same plant was interviewed again in the later waves.

4.2 Samples

In the empirical analysis, we use two samples constructed from the datasets described above.

WorldBase Sample

This sample is constructed exclusively from the WorldBase dataset. It is used to test the predictions related to integration. We exclude firms that have less than 20 employees, to correct for differences in the coverage of small firms across countries (see also Klapper, Laeven, and Rajan, 2006). To keep the analysis tractable, we restrict the attention to firms that have a primary SIC code in manufacturing (between SIC 2000 and 3999) that integrate at least one input different from their primary output j.

The Worldbase sample includes 67,111 plants, corresponding to 66,102 firms, operating in 459 sectors, located in 19 countries. Table A-2 reports the number of observations (at the firm-input level) by country.[28] This sample features more variation in plant size compared to the matched sample: median plant employment is 42, the mean is 147, and the standard deviation is 3,187 (see row "Worldbase Sample" in Table A-1).

Matched Sample

This is the sample that is used to test the predictions related to delegation, constructed by combining information from WorldBase and the WMS. Notice that the we are not able to use the full WMS to test the model's predictions concerning the role of input value and uncertainty on delegation choices. This is because testing predictions P.1 and P.3 requires information on ownership and input-output linkages between the plant surveyed in the WMS

written endorsement of many institutions like the Bundesbank, Banque de France, UK Treasury, and World Bank, and (iii) high quality MBA-type students were hired to run the surveys.

[28] Comparing Table A-2 with A-3, notice that one country (Greece) is missing in the WorldBase sample. This is because establishments in Greece only report their primary SIC codes. As a result, we cannot use within-firm variation to study the determinants of integration choices.

and its central headquarters, which we can only get for plants that are also in the WorldBase sample.

For the US and Canada we have linked plants interviewed in the WMS to plants in WorldBase using a common plant identifier (the DUNS number). For the remaining countries, there is no common plant identifier, so have used a string matching algorithm based on company names and location information to link plants in the WMS to firms in WorldBase. We then manually checked the results of the matching process. To construct firm-level variables, we have used ownership information from Worldbase to identify the parent of any matched plant.

As mentioned above, the WMS is focused on medium-sized plants, while WorldBase contains lots of very small plants. The matched sample includes 3,444 plant observations located in 20 countries, operating in 574 sectors, and corresponding to 2,883 firms.

As shown in Table A-1, this is a representative sample from the WMS: median plant employment is 150, the mean is 254, and the standard deviation is 367 (see row labeled "WMS sample"). Table A-3 reports the number of observations (at the plant level) by country in the matched sample.[29]

4.3 Key Variables

In what follows, we define the main variables used in the empirical analysis. Tables A-5 and A-4 in the Empirical Appendix present summary statistics for these variables.

Integration

To distinguish between integrated and non-integrated inputs, we rely on the methodology of Fan and Lang (2000), combining information on firms' reported activities with Input-Output tables (see also Acemoglu *et al.*, 2009; and Alfaro *et al.*, 2016).

Given the difficulty of finding highly disaggregated input-output matrices for all the countries in our dataset, we use U.S. input-output tables to provide a standardized measure of input requirements for each output sector.[30] The data are from the Benchmark Input-Output Tables of the Bureau of Economic Analysis (BEA), which include the make table, use table, and direct and total requirements coefficients tables. We employ the Use of Commodities by Industries after Redefinitions 1992 (Producers' Prices) tables. The BEA uses six-digit industry codes, while the classification of production activities in WorldBase follows the SIC classifi-

[29]Notice that the number of observations is larger than the number of plants, since a few plants were interviewed in more than one wave of the WMS.

[30]As pointed out by Acemoglu, Johnson and Mitton (2009), assuming that the U.S. input-output structure carries over to other countries mitigates concerns about the endogeneity of technology.

cation. We convert the input-output data at the 4-digit SIC level, using the concordance guide provided by the BEA.[31]

We use the primary SIC4 code reported by a firm to identify the relevant output sector j. For each sector j the I-O Tables report the dollar value of i used directly as an input in the production of \$1 of j, also known as the direct requirements coefficient, $IO_{i,j}$. We can use these coefficients to identify the set of 4-digit SIC inputs $S(j)$ — including both manufacturing and non-manufacturing inputs — that are used in the production of j, namely: $S(j) = \{i : IO_{i,j} > 0\}$.

To identify which inputs a firm integrates, we define $I(f) \subseteq S(j)$ to be the set of the primary and secondary SIC codes reported by firm f and all its subsidiaries (if any) in WorldBase, that are inputs in the production of the firm's output. This set identifies the integrated inputs, which the firm can in principle obtain within its ownership boundaries. The complement set $NI(f) = S(j) \setminus I(f)$ identifies the non-integrated inputs, i.e. the inputs required in the production of the firm's output that are not included in $I(f)$.

Having identified the set of integrated and non-integrated inputs for each firm f, we can then construct the dummy variable *Integration*$_{f,j,i}$, which is equal to 1 if firm f producing primary output j integrates a supplier in input industry i within its boundaries.

The BEA input-output table that we are using is highly disaggregated (based on 935 4-digit SIC industries). As a result, even when focusing on the top 100 inputs, the average probability that a firm integrates any input is only around 1 percent (see Table A-5).

In our empirical analysis, we will exploit variation in *Integration*$_{f,j,i}$ within and across firms to study how input risk and input value shape integration choices. To keep the analysis tractable, we will limit the sample to firms that integrate at least one input different from their primary output j, and to the top 100 inputs i used by j, as ranked by the IO coefficients (see also Alfaro *et al.*, 2019).

Delegation

Our measure of delegation comes from the WMS. Plant managers were asked several questions about the extent to which their central headquarters grant them autonomy in carrying out various activities. In particular, plant managers were asked to state the degree of autonomy they have when hiring a new full-time permanent shop floor employee, introducing a new product, or in sales and marketing decisions. These qualitative variables were scaled from a score of 1 (defined as all decisions taken at the corporate headquarters), to a score of

[31] The concordance table is based on the SIC 1987 classification. For codes for which the match is not one-to-one, we have randomized between possible matches.

5 (defined as complete autonomy granted to the plant manager). They were also asked how much capital investment they could undertake without prior authorization from the corporate headquarters. This is a continuous variable enumerated in national currency that is converted into dollars using PPPs.[32] Since the scaling may vary across questions, we have standardized the scores from the four autonomy questions to z-scores, by normalizing each question to mean zero and standard deviation one.[33]

The variable *Delegation*$_{f,p}$ is the average across the four z-scores for plant p belonging to firm f. We use information on ownership linkages from the WorldBase dataset to link a plant to its parent firm. Figure A-1 in the Empirical Appendix shows the distribution of *Delegation*$_{f,p}$ in the matched sample.

In the empirical analysis, we will examine whether firms are more likely to delegate decisions to suppliers of more valuable inputs. We will use the primary SIC4 code of the parent firm to identify the output industry j and the primary SIC4 code of the plant to identify the input industry i. As mentioned before, the WMS typically contains information on one plant per firm. This implies that, in the case of multi-plant firms, we can only observe the degree of autonomy granted by central headquarters to the manager of one their plants.[34] We will thus rely on cross-firm variation in *Delegation*$_{f,p}$ to identify the role of input value.

Input Value

To examine how input value affects delegation and integration choices, we will use the variable $IO_{i,j}$ described above. This is the direct requirement coefficient for the sector pair ij, which captures the dollar value of input i used in the production of one dollar of j.

Figure A-2 in the Empirical Appendix shows the distribution of $IO_{i,j}$ in the Worldbase sample. Not surprisingly, given that the BEA input-output tables are highly disaggregated, the average $IO_{i,j}$ is only 4 cents in the matched samples, and 5 cents in the WorldBase sample (see Tables A-5 and A-4).

[32] In Appendix Figure A-6, we detail the individual questions in the same order as they appear in the survey.

[33] The continuous measure of delegation using in the empirical analysis stands in apparent contrast to the binary delegation choice in the theoretical model. However, the two can be reconciled by supposing that the production process is subdivided into a number of tasks, each of which is subject to a problem shock, and can be delegated or centralized. HQ delegates a task whenever the supplier's productivity on it exceeds the threshold $y^*(\pi)$, and centralizes otherwise. Interpreting the number or fraction of tasks delegated as the degree of delegation yields a measure that has identical salient properties to the probability of delegation in the baseline model. See Section A-1.2 in the Theoretical Appendix for the details.

[34] In the case of single-plant firms, we can measure the degree of autonomy that the owner/CEO gives to the plant manager.

Uncertainty in Input Industries

In the theoretical model, the contribution of a non-integrated supplier depends on his ability to solve the problem θ that comes up during the production run. He produces $y(\theta)$ usable units will be produced, i.e., so his productivity is proportional to $y(\theta)$. Under the assumption that problems encountered are i.i.d. among suppliers in the same industry, the observed productivity distribution of non-integrated suppliers in industry i thus approximates the distribution $G_i(y)$.

By contrast, the model suggests that the observed productivity distribution of the integrated suppliers in industry i is not a good proxy for $G_i(y)$. This is because the contribution of an integrated supplier depends on whether or not HQ centralizes, which she does whenever the problem encountered is one for which the supplier has low competence. In that case it is HQ's own competence z that determines productivity. The observed productivity of integrated suppliers is thus left-censored. This can cloud the relationship between various orderings (most saliently, Rothschild-Stiglitz riskiness) of the observed distributions and orderings of the underlying distribution $G_i(y)$.[35]

We thus focus on non-integrated suppliers of input i and use information from the full WorldBase dataset on their labor productivity (sales per employee) to proxy for the distribution $G_i(y)$.[36] To minimize measurement error, we consider all plants that report SIC4 code i as their only production activity.[37]

The distribution of labor productivity of input suppliers approximates a lognormal distribution (see Figure A-3 in the Empirical Appendix).[38]

To test prediction P.3, we construct the variable *Mean Productivity*$_{i,c}$, the arithmetic average of labor productivity of suppliers of input i in country c. As mentioned in Section 3.4, this is a proxy for the mean of $G_i(y)$ in our model. Figure A-4 in the Empirical Appendix shows the distribution of *Mean Productivity*$_{i,c}$ in the Worldbase sample.

To assess the validity of prediction P.4, we use *CV Productivity*$_{i,c}$, the coefficient of variation of productivity of suppliers in the same input industry. Controlling for the mean of supplier productivity, this variable can be used as a proxy for riskiness of the input indus-

[35] Recall that non-integrated suppliers endogenously do not delegate, so there is no censoring problem for them. In addition to the theoretical reasons for not including integrated suppliers, transfer pricing effects may also distort their measured labor productivity.

[36] As shown in an earlier version of the paper, the results are robust to using data from Bloom *et al.* (2018) on stock market returns of US firms to capture cross-industry variation in supplier productivity.

[37] The results continue to hold if we consider all plants that report SIC code i as one of their production activities, including those integrated in larger firms.

[38] This figure has been constructed by regressing log labor productivity (sales/employee) of all independent suppliers in WorldBase on 4-digit-industry $\times$ country dummies. It thus shows within-industry-country variation in log labor productivity.

try in the Rothschild-Stiglitz sense (see Levy, 1973). Figure A-5 in the Empirical Appendix shows the distribution of *CV Productivity*$_{i,c}$ in the Worldbase sample.

In robustness checks, we construct *Mean Productivity*$_{i,c}$ and *CV Productivity*$_{i,c}$ after winsorizing labor productivity at the 5th and 95th percentile.

5 Empirical Results

5.1 The Effects of Input Value

In this section, we assess our model's predictions concerning the effects of input value on delegation and integration choices.

We first test prediction P.1 and verify how the technological importance of an input affects delegation choices. To this purpose, we exploit exogenous variation in technological importance of inputs captured by the the input-output coefficients $IO_{i,j}$ and estimate

$$\text{Delegation}_{f,p,i,j,c} = \alpha_1 \ \text{IO}_{i,j} + \alpha_2 \mathbf{X}_p + \alpha_3 \mathbf{X}_f + \delta_i + \delta_j + \delta_c + \epsilon_{f,p,i,j,c}. \quad (4)$$

using the matched sample. The dependent variable in (4) is the degree of autonomy granted to plant p (with primary activity i, located in country c) by parent firm f (with primary activity j, located in country c). The main control of interest is $IO_{i,j}$, the direct requirement coefficient for the sector pair ij. Some specifications include vectors of plant-level controls ($\mathbf{X}_p$), firm-level controls ($\mathbf{X}_f$), input-sector and output-sector fixed effects (δ_i and δ_j), and country fixed effects (δ_c).[39] Plant-level controls include the percentage of the plant's employees with a bachelor's degree or higher and the plant's share of the firm's employment. Firm-level controls include the employment and age of the parent firm. We cluster standard errors at the firm level.[40] Our theoretical models suggests that a producer of good j should delegate more decisions to integrated suppliers that produce more valuable inputs, implying that the α_1 coefficient should be positive and significant.

[39]Unlike in the integration regressions, we cannot include firm fixed effects in (4). As mentioned in Section 4, the WMS does not allows us to observe variation in delegation across plants belonging to the same firm. As a result, we cannot identify α_1 by comparing the degree of autonomy granted by firm f producing good j (e.g. automobiles) to the managers of two of its plants, one producing input i (e.g. plastics materials and resins), the other producing input i' (e.g. engines). We can, however, identify the role of input value by exploiting cross-firm variation in the degree of delegation. In particular, we can compare the degree of autonomy granted by two firms producing the same output (e.g. automobiles) to the managers of one of their plants, one producing input i (e.g. plastics materials and resins), the other producing input i' (e.g. engines). We can also compare the degree of autonomy granted to two plants producing the same input i (e.g. plastics materials and resins) who belong to firms making different final goods (e.g. automobiles and fabricated pipe and fittings).

[40]The results are practically identical if we cluster at the industry-pair level.

The results of estimating (4) are reported in Table 1. We present first a specification that includes the key control variable with input-industry fixed effects (column 1), and then further include country fixed effects (column 2), output-industry fixed effects (column 3), and the plant and firm controls (column 4).

Table 1

Delegation and input value

	(1)	(2)	(3)	(4)
$IO_{i,j}$	0.9865***	0.9371**	0.9801**	1.0475**
	(0.3789)	(0.3795)	(0.4522)	(0.4443)
Input FE	Yes	Yes	Yes	Yes
Output FE	No	No	Yes	Yes
Country FE	No	Yes	Yes	Yes
Plant controls	No	No	No	Yes
Firm controls	No	No	No	Yes
Noise controls	Yes	Yes	Yes	Yes
Number of observations	3,179	3,179	3,179	3,179

Notes: The dependent variable is $Delegation_{f,p,i,j,c}$, the degree of autonomy granted to plant p (with primary activity i, located in country c) by the parent firm f (with primary activity j). $IO_{i,j}$ is the direct requirement coefficient for the sector pair ij. Plant-level controls include the percentage of the plant's employees with a bachelor's degree or higher and the plant's share of the firm's employment. Firm-level controls include the employment and age of the parent firm. Output and input fixed effects are respectively the primary activities of the parent and of the plant (defined at 3-digit SIC). Standard errors clustered at the firm level in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels respectively.

As expected, the coefficient of $IO_{i,j}$ is positive and significant across all specifications, indicating that suppliers of more important inputs are granted more authority from central headquarters. In terms of magnitude, based on the estimates reported in column 3 of Table 1, increasing the input-output coefficient by one standard deviation increases delegation by around 0.035 standard deviations.[41]

The coefficients of the auxiliary firm controls in column 4 of Table 1 indicate that larger and older firms are more likely to delegate decisions to their suppliers and that plants that are larger and have a more educated workforce are granted more autonomy, in line with Bloom, Sadun and Van Reenen (2012).

[41]The standard deviation of $IO_{i,j}$ in the matched sample is 0.035, so 0.980*0.035 = 0.034. This effect might appear to be a small, but can be compared to the effect of other covariates. For example, the coefficient of log firm employment in column 4 of Table 1 is 0.088, which indicates that a a big increase in firm employment of 40% is only associated with a 0.088*0.4=0.036 standard deviation change in the decentralization index.

As shown in Table A-6, the results of Table 1 are robust to using more disaggregated industry fixed effects (defined at the SIC4 level) to control for the primary activities of the plant and of its parent firm. The coefficient β_1 remains positive and significant, in line with prediction P.1. One may be concerned that our baseline results include single-plant firms, for which the primary activity of the parent (identifying output j) coincides with the primary activity of the plant (identifying input i). For these firms, the role of input value is identified by variation along the diagonal of the IO matrix. To address this concern, we have verified that our results are robust to excluding single-plant firms (see Table A-7) and further restricting the analysis to plants that operate in a different SIC3 industry than their parent firm (see Table A-8). Notwithstanding the much reduced sample size, the coefficient of $IO_{i,j}$ remains positive and significant in all but one specification.

We next examine whether final good producers are more likely to integrate suppliers of more valuable inputs, in line with prediction P.2. To test this, we estimate the following linear probability model using the WorldBase sample:

$$\text{Integration}_{f,j,i,c} = \alpha_1 \, \text{IO}_{i,j} + \alpha_2 \, \mathbf{X}_f + \alpha_i + \delta_j + \delta_c + \epsilon_{f,j,c,i}. \tag{5}$$

The dependent variable is the probability that firm f (with primary activity in sector j and located in country c) integrates input i within its boundaries, $\mathbf{X}_f$ is a vector of firm-level controls, and δ_i and δ_j denotes respectively input-industry, output-industry, and country fixed effects. In the most demanding specifications, we exploit only within-firm variation to identify the role of input value. In these specifications, we replace output-sector and country fixed effects with firm fixed effects (δ_f), which allow us to account for the role of unobservable firm characteristics. We cluster standard errors at the input-output level, the same as $IO_{i,j}$, the key variable of interest.[42] Our theoretical models suggests that a producer of good j should be more likely to integrate suppliers of more valuable inputs, implying that $\alpha_1 > 0$.

The results are reported in Table 2. We first regress $Integration_{f,j,i,c}$ against the key control of interest, $IO_{i,j}$, and input-industry fixed effects (column 1). We then add country fixed effects (column 2), output-industry fixed effects (column 3), and additional firm-level controls (column 4). In the last specification, we include firm fixed effects, exploiting only within-firm variation in integration choices (column 5). In this specification, country and output-industry fixed effects are absorbed by the firm fixed effects (each firm f is associated to one location and one primary activity).

Across all specifications, the coefficient of $IO_{i,j}$ is positive and significant at the 1 percent

[42]The results of are unaffected if we use two-way clustering at the input and firm level: changes in the standard errors are minimal and $IO_{i,j}$ is always positive and significant at the 1 percent level.

level, confirming that final good producers are more likely to produce in house more valuable inputs, in line with prediction P.2 of our model. The coefficients of the auxiliary firm controls, indicate that larger and older firms are more likely to integrate inputs within their boundaries.

Table 2

Integration and input value

	(1)	(2)	(3)	(4)	(5)
$IO_{i,j}$	0.1443***	0.1445***	0.1704***	0.1702***	0.1922***
	(0.0205)	(0.0206)	(0.0247)	(0.0247)	(0.0278)
Input FE	Yes	Yes	Yes	Yes	Yes
Output FE	No	No	Yes	Yes	No
Country FE	No	Yes	Yes	Yes	Yes
Firm FE	No	No	No	No	Yes
Firm controls	No	No	No	Yes	No
Observations	7,042,966	7,042,966	7,042,966	7,042,966	7,042,966

Notes: The dependent variable is $Integration_{f,j,i,c}$, a dummy equal to 1 if firm f producing final product j (defined at 4-digit SIC) and located in country c integrates input i (defined at 4-digit SIC) within its boundaries. $IO_{i,j}$ is the direct requirement coefficient for the sector pair ij. Firm-level controls include the employment and age of the firm. Output and input fixed effects defined at 3-digit SIC. Standard errors clustered at the input-output level in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels.

In terms of magnitude, based on the specification of column 3, moving the input-output coefficient by one standard deviation increases the probability of vertical integration by 0.6 percentage points — a 60 percent increase compared to the baseline probability of one percentage point.[43]

We have carried out a series of additional estimations to verify the robustness of the results of Table 2. First, we verify the results are robust to using more disaggregated industry fixed effects (see Table A-9). Second, we consider alternative sample of firms. One may be concerned about measurement error in the vertical integration index. In an influential study, Atalay, Hortaçsu, and Syverson (2014) find little evidence of intra-firm shipments between related plants within the United States. This suggests that using Fan and Lang (2000)'s methodology to construct the integration variable may lead us to mis-classify some inputs as being integrated, when the firm is actually sourcing them from the market. Measurement error in the vertical integration index should work against us, making it harder to find a significant effect of input value on vertical integration. Nevertheless, we have verified that

[43]The standard deviation of $IO_{i,j}$ is 0.036. Thus, 0.170*0.036*100 = 0.612.

the effect of input risk on the integration probability holds even when we restrict the analysis to single-plant firms.[44] For these firms, measurement error in the vertical integration index should be less of a concern, since it is unlikely that a parent would not use the inputs produced in its own establishment. The coefficient of $IO_{i,j}$ remains positive and significant (see Table A-10). The results are also robust to restricting the analysis to firms included in the matched sample (see Table A-11).

Overall, the results of Tables 1 and 2 and the corresponding robustness checks support the model's predictions about the effects of input value on delegation and integration choices.

5.2 The Effects of Uncertainty

The model implies that uncertainty in input industries should affect both organizational choices. We first consider the impact of uncertainty on delegation choices and estimate

$$\begin{aligned} \text{Delegation}_{f,p,i,j,c} &= \beta_1 \text{ Mean Productivity}_{i,c} + \beta_2 \text{ CV Productivity}_{i,c} + \\ &+ \beta_3 \text{ IO}_{i,j} + \beta_4 \mathbf{X}_p + \beta_5 \mathbf{X}_f + \delta_i + \delta_j + \delta_c + \epsilon_{f,p,i,j,c}. \end{aligned} \tag{6}$$

using the matched WorldBase-WMS sample. As in (4), the dependent variable in (6) is the degree of autonomy granted to plant p by parent firm f. The main control of interest is *Mean Productivity*$_{i,c}$, the mean labor productivity of independent suppliers in industry i located in country c. According to prediction P.3, when controlling for *CV Productivity*$_{i,c}$, the coefficient of *Mean Productivity*$_{i,c}$ should be positive.

When estimating (6), we always include input-sector fixed effects to exploit variation in mean supplier productivity in a given input sector across countries. Some specifications additionally include vectors of plant-level controls ($\mathbf{X}_p$), firm-level controls ($\mathbf{X}_f$), output-sector fixed effects and δ_j), and country fixed effects (δ_c), as well as $IO_{i,j}$, the direct requirement coefficient for the sector pair ij. We report standard errors clustered at the input level.

The results of estimating (6) are reported in Table 3. The coefficient of *Mean Productivity*$_{i,c}$ is always positive and significant, confirming the predicted effect of first-order stochastic dominance on delegation choices (prediction P.3). Recall that the theory has no implications for the effect of *CV Productivity*$_{i,c}$ on delegation choice. As it happens, the coefficient of this variable is not statistically significant.

[44] In these regressions, we can only include one set of industry fixed effects (given that the primary SIC code of the parent firm coincides with the primary SIC code of the plant) and one employment variable (given that the number of employees of the plant and the firm are the same).

Table 3

Delegation and uncertainty

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mean Productivity$_{i,c}$	0.0280**	0.0284**	0.0326**	0.0344**	0.0266**	0.0276**	0.0332**	0.0355**
	(0.0114)	(0.0112)	(0.0131)	(0.0153)	(0.0116)	(0.0115)	(0.0134)	(0.0156)
CV Productivity$_{i,c}$	0.0032	0.0026	0.0032	0.0040	0.0025	0.0020	0.0026	0.0037
	(0.0040)	(0.0040)	(0.0045)	(0.0050)	(0.0040)	(0.0040)	(0.0045)	(0.0045)
IO$_{i,j}$					0.9863**	0.9729**	1.1332**	1.2088***
					(0.3938)	(0.3932)	(0.4681)	(0.4592)
Input FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Output FE	No	No	Yes	Yes	No	No	Yes	Yes
Country FE	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Noise controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Plant controls	No	No	No	Yes	No	No	No	Yes
Firm controls	No	No	No	Yes	No	No	No	Yes
Observations	2,928	2,928	2,928	2,928	2,889	2,889	2,889	2,889

Notes: The dependent variable is *Delegation*$_{f,p,i,j,c}$, the degree of autonomy granted to plant p (with primary activity i, located in country c) by the parent firm f (with primary activity j). *Mean Productivity*$_{i,c}$ is the mean of supplier productivity. *IO*$_{i,j}$ is the direct requirement coefficient for the sector pair ij. *CV Productivity*$_{i,c}$ is the coefficient of variation of labor productivity of the independent suppliers in input industry i located in country c. Plant-level controls include the percentage of the plant's employees with a bachelor's degree or higher and the plant's share of the firm's employment. Firm-level controls include the employment and age of the parent firm. Output and input fixed effects defined at 3-digit SIC. Standard errors clustered at the input level in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels.

In terms of magnitude, based on the estimates reported in column 3 of Table 3, mean supplier productivity by one standard deviation increases delegation by around 0.032 standard deviations.[45]

We have verified that the results of Table 3 are robust to using more disaggregated industry fixed effects (see Table A-12). We have also constructed the variables *Mean Productivity*$_{i,c}$ and *CV Productivity*$_{i,c}$ after winsorizing labor productivity at the 5th and 95th percentile (Table A-13) In all specifications, the coefficient of the variable *Mean Productivity*$_{i,c}$ remains positive and significant, in line with prediction P.3.

To assess the validity of prediction P.4 on the impact of risk on integration, we estimate the linear probability model

$$\begin{aligned} \text{Integration}_{f,j,i,c} \quad = \quad & +\alpha_1 \text{ Mean Productivity}_{i,c} + \alpha_2 \text{ CV Productivity}_{i,c} \\ & \alpha_3 \text{ IO}_{i,j} + \beta_4 \mathbf{X}_f + \delta_i + \delta_j + \delta_c + \epsilon_{f,j,c,i}. \end{aligned} \tag{7}$$

using the WorldBase sample. As in (5), the dependent variable is the probability that firm f (with primary activity in sector j and located in country c) integrates input i within its boundaries. The main control of interest is *CV Productivity*$_{i,c}$, the coefficient of variation of labor productivity of independent suppliers in input industry i in country c. According to prediction P.4, when controlling for *Mean Productivity*$_{i,c}$, the coefficient of this variable should be positive and significant.

The results are reported in Table 4. We present first a specification that includes the key control variables with input-industry fixed effects (column 1), further include country fixed effects (column 2), the IO coefficient (column 3), output-industry fixed effects (column 4), and the firm controls (column 5). In the last specification, we replace country and output-industry fixed effects with firm fixed effects (column 6).

In all specifications, the estimated coefficient for *CV Productivity*$_{i,c}$ is positive and significant at the 1 percent level. This finding is robust to including additional controls and different sets of fixed effects. In particular, it continues to hold when including firm fixed effects. In this specification, the coefficients α_1 is identified by exploiting only within-firm variation in the dispersion of supplier productivity across input industries.

[45] The standard deviation of *Mean Productivity*$_{i,c}$ in the matched sample is 0.033, so 0.033*0.97=0.032. Again, we can compare this magnitude with the effect of employment: according to the specification in column 4 of Table 3, a 40% change in the parent firm's employment is associated with a 0.095*0.4=0.038 standard deviation change in the delegation index.

Table 4

Integration and uncertainty

	(1)	(2)	(3)	(4)	(5)	(6)
Mean Productivity$_{i,c}$	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
CV Productivity$_{i,c}$	0.0006***	0.0008***	0.0008***	0.0007***	0.0007***	0.0007***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
IO$_{i,j}$			0.1499***	0.1791***	0.1789***	0.2030***
			(0.0134)	(0.0145)	(0.0145)	(0.0161)
Input FE	Yes	Yes	Yes	Yes	Yes	Yes
Output FE	No	No	No	Yes	Yes	-
Country FE	No	Yes	Yes	Yes	Yes	-
Firm FE	No	No	No	No	No	Yes
Firm controls	No	No	No	No	Yes	No
Observations	6,644,884	6,644,884	6,644,884	6,644,884	6,644,884	6,644,884

Notes: The dependent variable is *Integration*$_{f,j,i,c}$, a dummy equal to 1 if firm f producing final product j (defined at 4-digit SIC) and located in country c integrates input i (defined at 4-digit SIC) within its boundaries. *CV Productivity*$_{i,c}$ is the coefficient of variation of labor productivity of the independent suppliers in input industry i located in country c. *Mean Productivity*$_{i,c}$ is the mean of supplier productivity. *IO*$_{i,j}$ is the direct requirement coefficient for the sector pair ij. Firm-level controls include the employment and age of the parent firm. Output and input fixed effects defined at 3-digit SIC. Standard errors clustered at the input level in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels.

These results provide strong support for prediction P.4. Increases in risk increase the option value of integration: when the ability of suppliers to solve problems that might arise during production is more uncertain, HQ values more the option of being able to centralize or delegate production decisions. When productivity is distributed lognormally, as it is the case in our data, this effect dominates the (ambiguous) effect on the cost of integration, so firms should be more likely to integrate suppliers in riskier input industries.

As for the economic magnitude of the effects, based on the specification in column 3, a one-standard-deviation increase in *CV Productivity*$_{i,c}$ increases the probability of integrating a supplier by around 0.34 percentage points. This corresponds to a 34% increase relative to the baseline integration probability of one percentage point.[46]

We have performed a series of additional estimations to verify the robustness of the results reported in Table 4. We have verified that the results continue to hold when using more disaggregated industry fixed effects (see Table A-14). We have constructed the variable *CV Productivity*$_{i,c}$ after winsorizing labor productivity at the 5th and 95th percentile (Table A-15). We have restricted the analysis to single-plant firms (see Table A-16). As mentioned before, for these firms, measurement error in the integration variable should be less of a concern. We have focused on the matched sample instead of using the larger WorldBase sample (Table A-17). Finally, we have constructed the variables *CV Productivity*$_{i,c}$ and *Mean Productivity*$_{i,c}$ after restricting the analysis to input industries in which there are at least 50 suppliers in each input industry-country (Table A-18), to rule out that the results of Table 4 are due to demand-driven supply assurance motives for integration (see discussion in Section 5.3.1). In all these robustness checks, the coefficient of the variable *CV Productivity*$_{i,c}$ remains positive and highly significant.

5.3 Discussion

Our empirical analysis establishes the following regularities: (i) firms delegate more decisions to integrated suppliers that produce more valuable inputs; (ii) firms are more likely to integrate suppliers of more valuable inputs; (iii) firms delegate more decisions to integrated suppliers in more productive input industries; (iv) firms are more likely to integrate inputs in industries in which supplier productivity is more dispersed.

These results can be rationalized by our theoretical model, in which integration creates a real option for HQ to centralize or delegate decisions according to comparative advantage, and the value of this option increases with the degree of uncertainty about suppliers' ability to solve problems that may arise during the production process.

[46]The standard deviation of CV Productivity$_{i,c}$ is 4.63, thus 0.0007*4.63*100 =0.342.

5.3.1 Other Theories

Existing alternative models could provide a rationale for some — but not all — of our empirical findings. For instance, as suggested earlier, the model in Legros and Newman (2013) could explain the finding that the likelihood that a supplier is integrated grows with the input's contribution to total firm value. However, that model does not consider the possibility of delegation and thus cannot rationalize the findings about its determinants; nor does it account for the empirical effects of risk on integration.

The finding that the likelihood that a supplier is integrated grows with the riskiness of the input industry is related to the literature on supply assurance motives for integration (e.g., Carlton, 1979; Bolton and Whinston, 1993; Baker, Gibbons, and Murphy, 2002). In these models, the assurance motive is driven by uncertainty resolved after input production (e.g., product demand), possibly augmented by the supplier's hold-up behavior. Broadly speaking, one would expect less integration when there is less of a risk of suppliers coming up short, for technological or behavioral reasons. These could provide an explanation for the positive coefficient of $\textit{CV Productivity}_{i,c}$ in Table 4.

However, we should expect these demand-driven mechanisms, particularly the variants in which suppliers opportunistically sell to other buyers, to be less relevant when firms can source inputs from many suppliers. Against this hypothesis, the coefficient of $\textit{CV Productivity}_{i,c}$ remains positive and highly significant when focusing on input industries with large numbers of suppliers (see Table A-18). Moreover, the result holds when we include output industry fixed effects, which account for product market uncertainty (see columns 4 and 5 of Tables 4 and the corresponding specifications in Tables A-14-A-18) and firm fixed effects, which account for demand for inputs by other firms in the same country-output sector (see column 6 of Tables 4 and the corresponding specifications in Tables A-14-A-18).

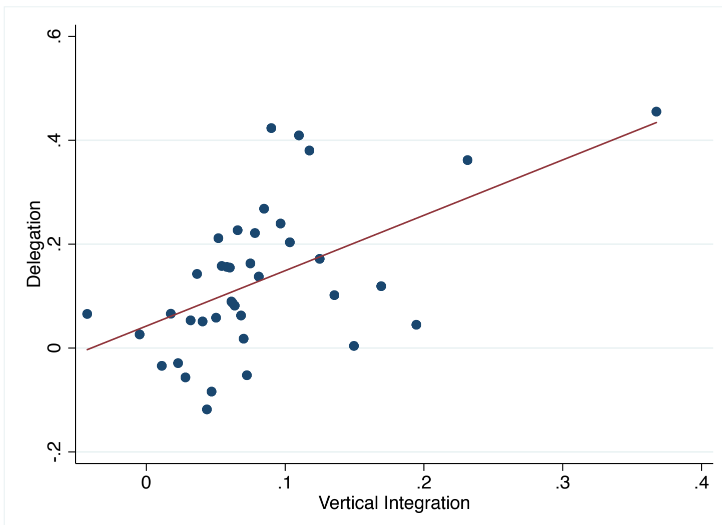
Finally, while existing models of supply assurance could in principle explain why suppliers in riskier industries are more likely to be integrated, they do not rationalize the other empirical findings, since they neither have anything to say about delegation, nor address the role of input value in integration decisions.

5.3.2 The Co-Variation of Integration and Delegation

As discussed at the end of Section 3.2.2, our analysis suggests that higher value enterprises (e.g., that can sell their goods at higher prices or have more capable HQs) should be more vertically integrated while simultaneously granting more autonomy to their subordinates. Indeed, our data shows that more vertically integrated firms tend to delegate more.

This can be seen by looking at Figure 2, in which we regress $\textit{Delegation}_{f,p}$ (the degree of autonomy granted by firm f to plant p) against *Vertical Integration*$_f$ (the vertical integration index of firm f, as defined in Alfaro *et al.*, 2016), including input-industry fixed effects, and noise controls. The regression is based on our matched sample; the figure is a binned scatterplot of the residuals of that regression. The positive covariation between integration and delegation is robust to including additional (output-industry and country) fixed effects, as well as the firm-level and plant level controls used in our empirical analysis (e.g. size and age of the firm, size of the plant and education of its workforce).

Figure 2: Firm-Level Delegation and Vertical Integration



This evidence presents something of a paradox in light of "one-dimensional" organizational models that do not distinguish between decentralizing decisions formally via transfers of ownership (outsourcing), and decentralizing them informally within the firm boundaries (delegation). Guided by such models, one would tend to equate complete non-integration and complete delegation — both seem to put decisions as far removed from the "center" as possible — implying that integration and delegation should covary negatively in the data. But the pattern is a natural consequence of a two-dimensional model of delegation and integration, via the value principle.[47]

[47]The covariation of delegation and integration could potentially be rationalized by managerial capacity models in which an HQ's attention is a scarce corporate resource (e.g., Geanakoplos and Milgrom, 1991; Aghion and Tirole, 1995): if vertical integration increases the scope of decisions in a firm, HQ may simply need to cede control to lower-level managers. However, there are grounds for skepticism. Among them, the positive correlation between delegation and integration is robust to controlling for measures of firm size and workforce

6 Conclusion

Organizations are complicated. Understanding them entails simplification, and a lot has been learned by isolating distinct organizational design elements. But there are costs to isolation. Formally similar models that focus only on one dimension or another of the organization (integration or centralization) can mislead when embedded in two dimensions (integration and centralization might be predicted to covary positively, unlike in our model or in the data).

In this paper, we have brought integration and delegation together, both theoretically and empirically. A number of insights emerge from the exercise, which is founded on the well-known conceptual distinction between informal delegation and formal outsourcing. First, the two respond differently to exogenous environmental parameters: outsourcing decrease with an input's value contribution, delegation increases. They also respond to differently to distinct dimensions of uncertainty.

Second, it is often argued that managerial authority under integration leads various rigidities that are in turn the cost of integration. Our analysis suggests that, on the contrary, integration may actually increase managerial flexibility, because it facilitates the re-allocation of decision-making across different parts of the organization in light of new information. In the more nuanced view that emerges from a multidimensional approach, it is only a particular form of integrated ownership structure — centralization — that appears rigid.

Third, studying integration and delegation together reveals a novel mechanism by which supply assurance motivates integration: redeployment of control to the most competent solver of problems that present themselves ensures a minimal level of productivity. Formally, this places the evaluation of the costs and benefits of ownership in the rubric of real option theory.

Finally, the framework also reveals unifying principles that permeate various aspects of organizational design. In particular, it extends the value principle, applied to integration in previous work, to delegation: the value of an input or the profitability of a firm affect how much autonomy the input's supplier will be given. Many studies, especially in the management literature, see delegation (decentralization within firms) as a tool for generating better performance, say by improving incentives or morale. One implication of the value principle is that positive correlations between productivity and delegation should be interpreted with caution, since causality could also run in the opposite direction: exogenously more produc-

education that could proxy for, or at least correlate with, managerial capacity. Those measures are themselves positively correlated with delegation (see Table 1), whereas a managerial capacity model would tend to predict that firms with more capacity should delegate less. Finally, capacity-constrained HQs would keep control of the decisions regarding more important inputs and delegate decisions concerning less important ones, which goes against the evidence in result (i) above: more autonomy is granted to suppliers of more, not less, important inputs.

tive firms will be more willing to delegate, and suppliers with a lot of control may be ones who have encountered problems they are good at solving.

As evidence mounts that organization matters for the performance of individual firms, industries, and aggregate economies, it is becoming ever more imperative to understand the functioning of organizations as a whole rather than just their parts. Studying firm boundaries together with other aspects of the firm's internal organization helps to illuminate interdependencies that are crucial for understanding the functioning and guiding the design and regulation of organizations. For instance, if recent global growth in uncertainty is manifested as higher input risk, a wave of vertical mergers may be on the horizon, as the option value of owning suppliers increases. Unlike versions of supply assurance theory that have linked vertical integration to market foreclosure, our model suggests that these mergers should generate little concern from antitrust authorities: by increasing flexibility, integration allows firms to increase productivity and product quality, to the benefit of consumers.

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Appendices (for Online Publication Only)

A-1 Theoretical Appendix

A-1.1 Integration, Risk, and the Log-normal Distribution

Integration occurs if

$$\frac{z\pi - \overline{c}}{v(\pi)} \geq \mathbb{E}[y|y < y^*(\pi)].$$

It increases (in the sense that it occurs for a larger set of parameters $\overline{c}, z, \pi$) in response to changes in distribution if $\mathbb{E}[y|y < y^*(\pi)]$ decreases. In general, changes in this conditional expectation resulting from changes in the riskiness of the underlying distribution could have either sign, but we can be more definitive for certain families.

If y is drawn from the family of log-normal distributions with parameters μ, σ, then the c.d.f. is $\Phi(\frac{\ln y - \mu}{\sigma})$, where $\Phi(\cdot)$ is the standard normal c.d.f, which is log-concave. The conditional expectation can be written (notationally suppressing dependence of y^* on π)

$$e^{\mu + \frac{\sigma^2}{2}} \cdot \frac{\Phi(\frac{\ln y^* - \mu}{\sigma} - \sigma)}{\Phi(\frac{\ln y^* - \mu}{\sigma})}.$$

One lognormal (μ', σ') is riskier than another (μ, σ) if their means $e^{\mu + \frac{\sigma^2}{2}}$ and $e^{\mu' + \frac{\sigma'^2}{2}}$ are equal and $\sigma' > \sigma$. Denoting $m = \mu + \frac{\sigma^2}{2}$, and rewriting $\mathbb{E}[y|y < y^*]$ in terms of m and σ, higher risk lowers the conditional expectation if and only if

$$\frac{\partial}{\partial \sigma} e^m \cdot \frac{\Phi(\frac{\ln y^* - m}{\sigma} - \frac{\sigma}{2})}{\Phi(\frac{\ln y^* - m}{\sigma} + \frac{\sigma}{2})} < 0. \tag{8}$$

Straightforward computation reveals that this condition is equivalent to

$$\frac{\phi(\frac{\ln y^* - m}{\sigma} + \frac{\sigma}{2})}{\Phi(\frac{\ln y^* - m}{\sigma} + \frac{\sigma}{2})}(\frac{1}{2} - \frac{\ln y^* - m}{\sigma^2}) - \frac{\phi(\frac{\ln y^* - m}{\sigma} - \frac{\sigma}{2})}{\Phi(\frac{\ln y^* - m}{\sigma} - \frac{\sigma}{2})}(\frac{1}{2} + \frac{\ln y^* - m}{\sigma^2}) < 0,$$

where $\phi(\cdot)$ is the standard normal density.

Now, logconcavity implies $\frac{\phi(\frac{\ln y^* - m}{\sigma} + \frac{\sigma}{2})}{\Phi(\frac{\ln y^* - m}{\sigma} + \frac{\sigma}{2})} < \frac{\phi(\frac{\ln y^* - m}{\sigma} - \frac{\sigma}{2})}{\Phi(\frac{\ln y^* - m}{\sigma} - \frac{\sigma}{2})}$. And because $y^* = z\frac{\pi}{v(\pi)} > z$, under the maintained hypothesis that $z > \mathbb{E}y$, $\ln y^* > m$, so $\frac{1}{2} + \frac{\ln y^* - m}{\sigma^2}$ is positive and exceeds $\frac{1}{2} - \frac{\ln y^* - m}{\sigma^2}$. It follows that condition (8) is satisfied, and we conclude that increasing riskiness of lognormal distributions implies more integration.

A-1.2 Multiple Tasks Extension

In the model described in Section 3, delegation is a binary variable: HQ either centralizes or delegates the production of an input to an integrated supplier. Below we extend the model to allow for multiple tasks to be performed by each supplier. This allows us to generate a continuous delegation choice, in line with the measure of delegation used in our empirical analysis.

Suppose that the basic input production stage is subdivided into many tasks $t \in \{1, \ldots, T\}$. Problem θ arises at the beginning of the stage, at which time negotiation over the delivery price proceeds (thus is dependent on $y = y(\theta)$).

For each task there is also a set of "sub-problems" $\eta \in [0, 1]$; the supplier deals with them with efficacy $\epsilon(\eta)$, a function that like $y(\theta)$ is known to both the supplier and HQ (and as with $y(\cdot)$, assume $\epsilon(\cdot)$ is increasing). Examples of the different tasks might include developing processes to manufacture a new product (where the product itself is represented by θ), acquiring machinery to produce it, and hiring employees to operate the machines. The main problem θ and the sub-problems η_t combine to generate a productivity on each task $x_t = X(y(\theta), \epsilon(\eta_t))$, where θ has the distribution F (and $y = y(\theta)$ the distribution G) from the text, the ϵ_t are i.i.d. across t, and independent of y, such that $\mathbb{E}x_t|y = y$ (for instance, $x_t = y + \epsilon_t$, with $\mathbb{E}\epsilon_t = 0$, or $x_t = y \cdot \epsilon_t$, with $\mathbb{E}\epsilon_t = 1$). Let $H(x_t)$ denote the c.d.f for x_t.

The ϵ_t are realized and observed after the single draw of y, but before task assignment. HQ has capability z on all tasks, and can separately delegate or retain control over each of them. Tasks contributes equally and additively to the overall supplier value, and costs of decisions s_t, h_t on each task are also weighted by $1/T$. Thus, overall surplus generated by HQ and the supplier is

$$\sum_t \frac{1}{T}\{[\mathbb{H}_t z + (1 - \mathbb{H}_t)X(y(\theta), \epsilon_t)][\pi p(|s_t - h_t|) - d(h_t)] - c(1 - s_t)\},$$

where $\mathbb{H}_t$ indicates whether HQ controls task t.

Similar to the text, centralizing a task results in choices $h_t = s_t = 0$ with payoff to HQ equal to $z\pi/T$, and cost imposed on the supplier $\bar{c}/T$. Under delegation the supplier chooses $s_t = 1$, resulting in zero cost to himself, and HQ responds with h_t that maximizes $(1/T)x_t[\pi p(|1 - h_t|) - d(h_t)]$, which yields her $(1/T)x_t v(\pi)$.

The delegation decision rule is similar as well: HQ delegates task t whenever $x_t v(\pi)/T > z\pi/T$. In other words, x_t replaces y in the benchmark model, and delegation occurs when $x_t > y^*(\pi)$. The probability of centralizing a task is $H(y^*(\pi))$, increasing in $y^*(\pi)$, therefore decreasing in π. So the task is delegated with probability $1 - H(y^*(\pi))$, increasing in π.

In this setting, the degree of delegation is simply the number (or fraction) of tasks delegated, which is very close to the delegation measure employed in our empirical analysis. It is a binomial random variable with parameters $(1 - H(y^*), T)$, which like the delegation probability of Result 1 is (stochastically) increasing in π.

This formulation modifies the integration calculation somewhat. For each task, HQ obtains value $\frac{1}{T}\max\{\pi z, v(\pi)x_t\}$, while the supplier bears cost $\overline{c}/T$ with probability $H(y^*(\pi))$. Thus the expected surplus from integration is

$$\sum_t \frac{1}{T}\left[\mathbb{E}_H \max\{\pi z, v(\pi)x_t\} - \overline{c}H(y^*(\pi))\right]. \tag{9}$$

Meanwhile, by reasoning analogous to that in the text, non-integration generates

$$\mathbb{E}_H \sum_t \frac{1}{T}\left[v(\pi)x_t\right]. \tag{10}$$

Note that expectations are with respect to H because the x_t are identically distributed. So integration occurs if expression (9) exceeds expression (10), which happens if and only if

$$\mathbb{E}_H \max\{\pi z - v(\pi)x_t, 0\} - \overline{c}H(y^*(\pi)) \geq 0,$$

where the choice of t is arbitrary because the expectations are equal for all t. This is formally identical to the condition (3) in the text, with x_t replacing y, and H replacing G. In particular, Result 2 on the dependence of integration π remains true here, because it depends only on the properties of $v(\pi)$ and $y^*(\pi)$, which are unchanged, and the fact that $z > \mathbb{E}_H x$, which, since $\mathbb{E}_H x = E_G y$, follows from the assumption that $z > \mathbb{E}_G y$.

As far as the effects of risk and stochastic dominance are concerned, it is now the effects of changes in the distribution H, rather than G, that matter. However, since delivery prices are based only on y (with bargaining occurring after y but before the ϵ_t are realized, the expected surplus to be split is $\mathbb{E}[\sum_t \frac{1}{T}v(\pi)x_t|y] = v(\pi)y$, so a typical non-integrated supplier's sales are proportional to y and independent of the $\{\epsilon_t\}$), it is effectively G that we observe in the data. So the question is whether riskier (stochastic dominant) G implies riskier (stochastic dominant) H.

We restrict attention to the lognormal case because that approximates the data as well as resolving a theoretical ambiguity in the effects of risk on integration. Suppose then that $x_i t = y\epsilon_i t$, and that not only $y_i \sim \text{LN}(\mu_i, \sigma_i^2)$ but also the $\epsilon_t \sim \text{LN}(0, \tau^2)$ (the notation signifies that variation across sectors i in the characteristics of the observed productivity distributions is driven entirely by variation in the y_i distribution, which according to the model is what is observed). Then $x_{it} = y_i\epsilon_t \sim \text{LN}(\mu_i, \sigma_i^2 + \tau^2)$, and changes in the y_i distributions have the desired effects: higher μ_i holding σ^2 (and τ) fixed correspond to stochastic increases in both the y_i and x_i distributions, while $(\mu_i + \frac{1}{2}\sigma_i^2)$-preserving increases in σ_i^2 and decreases in μ_i are also $(\mu_i + \frac{1}{2}[\sigma_i^2 + \tau^2])$-preserving and $\sigma_i^2 + \tau^2$-increasing, and therefore correspond to increases in the the riskiness of both y_i and x_i.

A-2 Empirical Appendix

A-2.1 Descriptive Statistics

Table A-1

Size of plants

	Mean	Median	Standard deviation	N. plants
WorldBase dataset	288	2	5,428	17,371,146
WMS dataset	277	150	405	11,691
Worldbase sample	147	42	3,187	67,111
Matched sample	254	150	367	3,444

Notes: The table reports statistics on the plants included in the WMS and WorldBase datasets, and in the samples used in our empirical analysis.

Table A-2

Observations by country, WorldBase sample

Country	Number of Observations	Percentage
Argentina	17,081	0.26
Australia	61,489	0.93
Brazil	3,857	0.06
Canada	149,022	2.24
Chile	4,570	0.07
China	558,337	8.40
France	35,617	0.54
Germany	1,985,864	29.89
India	101,107	1.52
Italy	412,315	6.20
Ireland	5,804	0.09
Japan	1,088,345	16.38
Mexico	30,865	0.46
New Zealand	44,824	0.67
Poland	28,116	0.42
Portugal	142,727	2.15
Sweden	17,319	0.26
United Kingdom	156, 962	2.36
United States	1,800,663	27.10
Total	6,664,884	100.00

Notes: The table reports the number of observations by country in the WorldBase sample. The observations are at the firm-input level. For each firm in the WorldBase sample, we consider the top 100 inputs (based on the IO coefficients) necessary to produce the firm's output.

Table A-3

Observations by country, matched sample

Country	Number of Observations	Percentage
Argentina	100	2.90
Australia	133	3.86
Brazil	234	6.79
Canada	207	6.01
Chile	95	2.76
China	64	1.86
France	212	6.16
Germany	224	6.50
Greece	104	3.02
India	104	3.02
Italy	106	3.08
Ireland	75	2.18
Japan	102	2.96
Mexico	86	2.50
New Zealand	118	3.43
Poland	27	0.78
Portugal	78	2.26
Sweden	330	9.58
United Kingdom	432	12.54
United States	613	17.80
Total	3,444	100.00

Notes: The table reports the number of plant observations by country in the matched sample.

Table A-4

Descriptive statistics of variables used in delegation regressions

	Mean	Median	Standard deviation	N. firms
Delegation$_{f,p,i,j,c}$	0.13	0.07	0.99	2,883
IO$_{i,j}$	0.04	0.04	0.035	2,428
Mean Productivity$_{i,c}$	0.27	0.17	0.97	2,253
CV Productivity$_{i,c}$	3.16	1.45	6.37	2,253
Share Employment$_p$	0.61	0.60	0.89	2,621
% Workers with College Degree$_p$	15.20	10.00	16.34	2,655
Employment$_f$	674.89	300.00	1,043.32	2,883
Age$_f$	40.08	30.00	35.02	2,883

Notes: The table reports descriptive statistics of the main variables used in the regressions of Tables 1 and 3. *Delegation*$_{f,p,i,j,c}$ is the overall degree of autonomy granted to plant p (with primary activity i, located in country c) by the parent firm f (with primary activity j). *Integration*$_{f,i}$ is a dummy equal to 1 if firm f integrates input i within its boundaries, measured at the 4-digit SIC level for the top 100 inputs of each industry j. *IO*$_{i,j}$ is the direct requirement coefficient for the sector pair ij, measured at the 4-digit SIC level for the top 100 inputs of each industry j. *Mean Productivity*$_{i,c}$ is the mean of labor productivity of the independent suppliers in input industry i located in country c (in millions of US Dollars), while *CV Productivity*$_{i,c}$ is the coefficient of variation of labor productivity. *Share Employment*$_p$ is the plant's share of the firm's employment. *% Workforce with College Degree*$_p$ is the percentage of the plant's employees with a bachelor's degree or higher. *Employment*$_f$ measures the number of employees of firm f. *Age*$_f$ is the number of years since the firm was established.

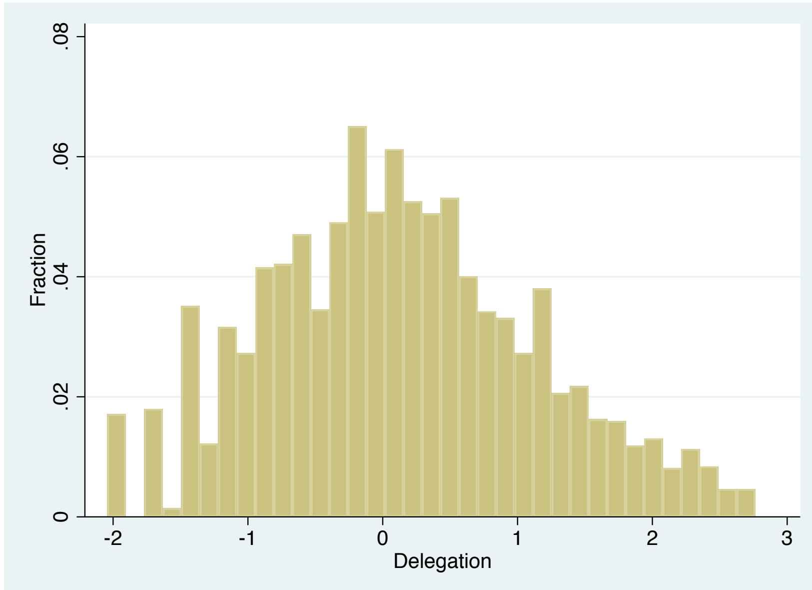
Table A-5

Descriptive statistics of variables used in integration regressions

	Mean	Median	Standard deviation	N. firms
Integration$_{f,j,i,c}$	0.01	0.00	0.11	66,102
IO$_{i,j}$	0.05	0.05	0.036	66,102
Mean Productivity$_{i,c}$	0.50	0.30	10.50	66,102
CV Productivity$_{i,c}$	3.04	1.94	4.63	66,102
Employment$_f$	206.38	45.00	4,903.87	66,102
Age$_f$	33.56	26.00	28.98	66,102

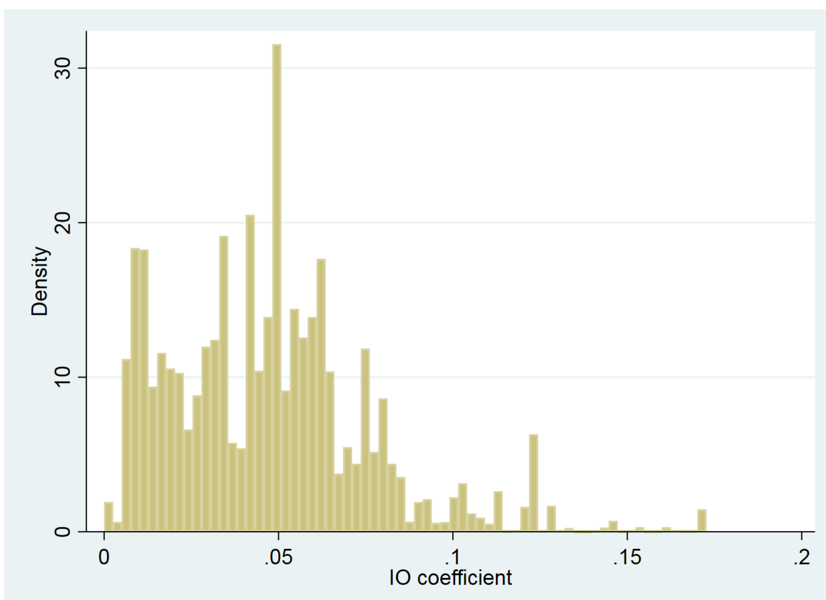
Notes: The table reports descriptive statistics of the variables used in Tables 2 and 4 (and robustness checks), based on the WorldBase sample. *Integration*$_{f,j,i,c}$ is a dummy equal to 1 if firm f producing final product j and located in country c integrates input i within its boundaries. *IO*$_{i,j}$ is the direct requirement coefficient for the sector pair ij, measured at the 4-digit SIC level for the top 100 inputs of each industry j. *Mean Productivity*$_{i,c}$ is the mean of labor productivity of the independent suppliers in input industry i located in country c (in millions of US Dollars), while *CV Productivity*$_{i,c}$ is the coefficient of variation of labor productivity. *Employment*$_f$ measures the number of employees of firm f. *Age*$_f$ is the number of years since the firm was established.

Figure A-1: Delegation



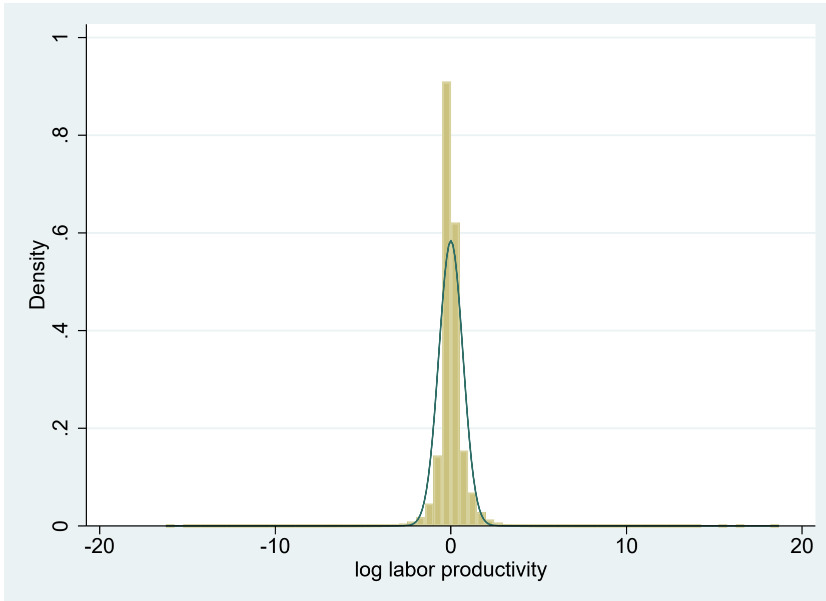
Notes: The figure shows the distribution of $Delegation_p$ in the matched sample.

Figure A-2: Input Value



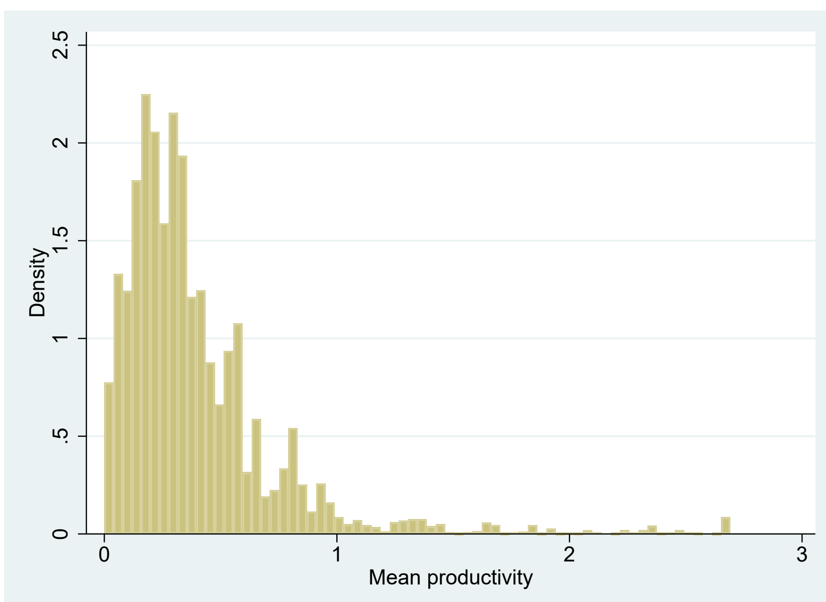
Notes: The figure shows the distribution of $IO_{i,j}$ in the WorldBase sample.

Figure A-3: Productivity Distribution of Suppliers



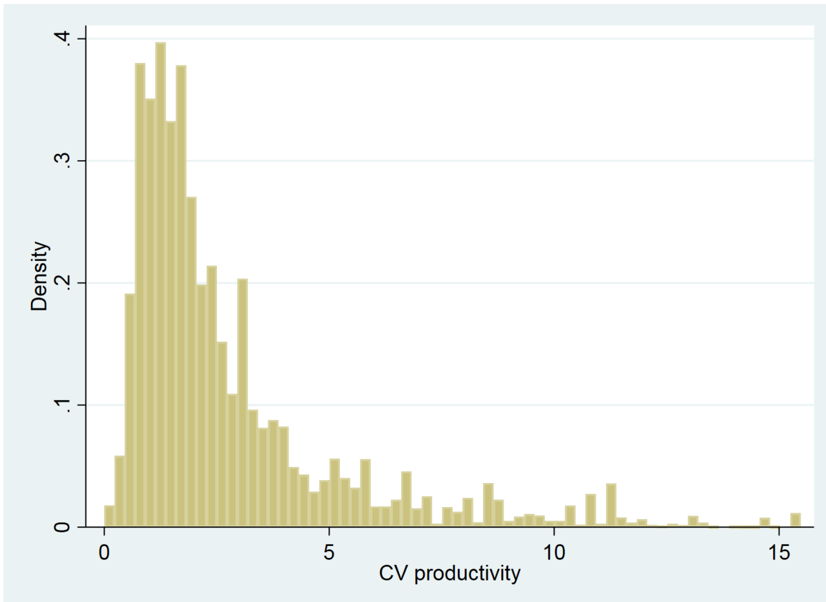
Notes: The figure shows the distribution of log labor productivity independent firms in the WorldBase sample. It has been constructed by regressing log labor productivity of all independent suppliers in WorldBase on 4-digit-industry × country dummies. It thus shows within-industry-country variation in log labor productivity.

Figure A-4: Mean Productivity



Notes: The figure shows the distribution of *Mean Productivity*$_{icj}$ in the WorldBase sample.

Figure A-5: Input Risk



Notes: The figure shows the distribution of *CV Productivity*$_{icj}$ in the WorldBase sample.

Figure A-6: Survey on Delegation

For Questions D1, D3, and D4 any score can be given, but the scoring guide is only provided for scores of 1, 3, and 5.

Question D1: "*To hire a FULL-TIME PERMANENT SHOPFLOOR worker what agreement would your plant need from CHQ (Central Head Quarters)?*"

Probe until you can accurately score the question—for example if they say "*It is my decision, but I need sign-off from corporate HQ.*" ask "*How often would sign-off be given?*"

	Score 1	Score 3	Score 5
Scoring grid:	No authority—even for replacement hires	Requires sign-off from CHQ based on the business case. Typically agreed (i.e. about 80% or 90% of the time).	Complete authority—it is my decision entirely

Question D2: "*What is the largest CAPITAL INVESTMENT your plant could make without prior authorization from CHQ?*"

Notes: (a) Ignore form-filling

(b) Please cross check any zero response by asking "*What about buying a new computer—would that be possible?*" and then probe….

(c) Challenge any very large numbers (e.g. >$¼m in US) by asking "*To confirm your plant could spend $X on a new piece of equipment without prior clearance from CHQ?*"

(d) Use the national currency and do not omit zeros (i.e. for a U.S. firm twenty thousand dollars would be 20000).

Question D3: "*Where are decisions taken on new product introductions—at the plant, at the CHQ or both*"?

Probe until you can accurately score the question—for example if they say "*It is complex, we both play a role*," ask "*Could you talk me through the process for a recent product innovation?*"

	Score 1	Score 3	Score 5
Scoring grid:	All new product introduction decisions are taken at the CHQ	New product introductions are jointly determined by the plant and CHQ	All new product introduction decisions taken at the plant level

Question D4: "*How much of sales and marketing is carried out at the plant level (rather than at the CHQ)*"?

Probe until you can accurately score the question. Also take an average score for sales and marketing if they are taken at different levels.

	Score 1	Score 3	Score 5
Scoring grid:	None—sales and marketing is all run by CHQ	Sales and marketing decisions are split between the plant and CHQ	The plant runs all sales and marketing

Question D5: "*Is the CHQ on the site being interviewed*"?

Notes: The electronic survey, training materials and survey video footage are available on www.worldmanagementsurvey.com

A-2.2 Robustness Checks

Table A-6

Delegation and input value (4-digits SIC industry FE)

	(1)	(2)	(3)	(4)
$IO_{i,j}$	0.9323**	0.8621*	1.1891*	1.4256**
	(0.4583)	(0.4641)	(0.7038)	(0.6914)
Input FE	Yes	Yes	Yes	Yes
Output FE	No	No	Yes	Yes
Country FE	No	Yes	Yes	Yes
Plant controls	No	No	No	Yes
Firm controls	No	No	No	Yes
Noise controls	Yes	Yes	Yes	Yes
Observations	3,179	3,179	3,179	3,179

Notes: The dependent variable is $Delegation_{f,p,i,j,c}$, the degree of autonomy granted to plant p (with primary activity i, located in country c) by the parent firm f (with primary activity j). $IO_{i,j}$ is the direct requirement coefficient for the sector pair ij. $Vertical\ Integration_f$ is the vertical integration index of firm f. $Employment_f$ measures the firm's employment, Age_f is the number of years since its establishment, $Share\ Employment_p$ is the plant's share of the firm's employment, and % $Workforce\ with\ College\ Degree_p$ is the percentage of the plant's employees with a bachelor's degree or higher. Output and input fixed effects are respectively the primary activities of the parent and of the plant (defined at 4-digit SIC). Standard errors clustered at the firm level in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels respectively.

Table A-7

Delegation and input value (only multi-plant firms)

	(1)	(2)	(3)	(4)
$\text{IO}_{i,j}$	1.1251**	1.0287*	1.4629**	1.5277**
	(0.5338)	(0.5445)	(0.6455)	(0.6289)
Input FE	Yes	Yes	Yes	Yes
Output FE	No	No	Yes	Yes
Country FE	No	Yes	Yes	Yes
Plant controls	No	No	No	Yes
Firm controls	No	No	No	Yes
Noise controls	Yes	Yes	Yes	Yes
Observations	1,861	1,861	1,861	1,861

Notes: The dependent variable is $Delegation_{f,p,i,j,c}$, the degree of autonomy granted to plant p (with primary activity i, located in country c) by the parent firm f (with primary activity j). $IO_{i,j}$ is the direct requirement coefficient for the sector pair ij. Plant-level controls include the percentage of the plant's employees with a bachelor's degree or higher and the plant's share of the firm's employment. Firm-level controls include the employment and age of the parent firm. Output and input fixed effects are respectively the primary activities of the parent and of the plant (defined at 3-digit SIC). Standard errors clustered at the firm level in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels respectively.

Table A-8

Delegation and input value
(excluding all plants in the same SIC3 industry as the parent firm)

	(1)	(2)	(3)	(4)
$\mathrm{IO}_{i,j}$	1.5074*	1.5513*	1.7700*	1.6437
	(0.8830)	(0.8957)	(1.0400)	(1.0941)
Input FE	Yes	Yes	Yes	Yes
Output FE	No	No	Yes	Yes
Country FE	No	Yes	Yes	Yes
Plant controls	No	No	No	Yes
Firm controls	No	No	No	Yes
Noise controls	Yes	Yes	Yes	Yes
Observations	989	989	989	989

Notes: The dependent variable is $Delegation_{f,p,i,j,c}$, the degree of autonomy granted to plant p (with primary activity i, located in country c) by the parent firm f (with primary activity j). $IO_{i,j}$ is the direct requirement coefficient for the sector pair ij. Plant-level controls include the percentage of the plant's employees with a bachelor's degree or higher and the plant's share of the firm's employment. Firm-level controls include the employment and age of the parent firm. Output and input fixed effects are respectively the primary activities of the parent and of the plant (defined at 3-digit SIC). Standard errors clustered at the firm level in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels respectively.

Table A-9

Integration and input value (4-digits SIC industry FE)

	(1)	(2)	(3)	(4)	(5)
$\text{IO}_{i,j}$	0.1471***	0.1472***	0.1756***	0.1755***	0.1991***
	(0.0205)	(0.0205)	(0.0248)	(0.0249)	(0.0283)
Input FE	Yes	Yes	Yes	Yes	Yes
Output FE	No	No	Yes	Yes	-
Country FE	No	Yes	Yes	Yes	-
Firm FE	No	No	No	No	Yes
Firm controls	No	No	No	Yes	No
Observations	7,042,966	7,042,966	7,042,966	7,042,966	7,042,966

Notes: The dependent variable is $\mathit{Integration}_{f,j,i,c}$, a dummy equal to 1 if firm f producing final product j (defined at 4-digit SIC) and located in country c integrates input i (defined at 4-digit SIC) within its boundaries. $IO_{i,j}$ is the direct requirement coefficient for the sector pair ij. Firm-level controls include the employment and age of the parent firm. Output and input fixed effects defined at 4-digit SIC. In the specification in column 5, country and output-industry fixed effects are absorbed by the firm fixed effects (each firm f is associated to one location and one primary activity). Standard errors clustered at the input-output level in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels.

Table A-10

Integration and input value (single-plant firms)

	(1)	(2)	(3)	(4)	(5)
$IO_{i,j}$	0.1393***	0.1396***	0.1643***	0.1643***	0.1849***
	(0.0204)	(0.0204)	(0.0247)	(0.0247)	(0.0278)
Input FE	Yes	Yes	Yes	Yes	Yes
Output FE	No	No	Yes	Yes	-
Country FE	No	Yes	Yes	Yes	-
Firm FE	No	No	No	No	Yes
Firm controls	No	No	No	Yes	No
Observations	6,361,633	6,361,633	6,361,633	6,361,633	6,361,633

Notes: The dependent variable is *Integration*$_{f,j,i,c}$, a dummy equal to 1 if firm f producing final product j (defined at 4-digit SIC) and located in country c integrates input i (defined at 4-digit SIC) within its boundaries. $IO_{i,j}$ is the direct requirement coefficient for the sector pair ij. Firm-level controls include the employment and age of the parent firm. Output and input fixed effects defined at 3-digit SIC. In the specification in column 5, country and output-industry fixed effects are absorbed by the firm fixed effects (each firm f is associated to one location and one primary activity). Standard errors clustered at the input-output level in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels.

Table A-11

Integration and input value (matched sample)

	(1)	(2)	(3)	(4)	(5)
$\text{IO}_{i,j}$	0.0485*	0.0645**	0.1016***	0.1014***	0.1067***
	(0.0290)	(0.0300)	(0.0186)	(0.0184)	(0.0194)
Input FE	Yes	Yes	Yes	Yes	Yes
Output FE	No	No	Yes	Yes	-
Country FE	No	Yes	Yes	Yes	-
Firm FE	No	No	No	No	Yes
Firm controls	No	No	No	Yes	No
Observations	292,744	292,744	292,744	292,744	292,744

Notes: The dependent variable is $\textit{Integration}_{f,j,i,c}$, a dummy equal to 1 if firm f producing final product j (defined at 4-digit SIC) and located in country c integrates input i (defined at 4-digit SIC) within its boundaries. $IO_{i,j}$ is the direct requirement coefficient for the sector pair ij. Firm-level controls include the employment and age of the parent firm. Output and input fixed effects defined at 3-digit SIC. In the specification in column 5, country and output-industry fixed effects are absorbed by the firm fixed effects (each firm f is associated to one location and one primary activity). Standard errors clustered at the input-output level in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels.

Table A-12

Delegation and uncertainty (4-digits SIC industry FE)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mean Productivity$_{i,c}$	0.0257**	0.0253**	0.0302*	0.0289*	0.0244*	0.0242**	0.0300*	0.0291*
	(0.013)	(0.0126)	(0.0160)	(0.0170)	(0.0128)	(0.0122)	(0.0159)	(0.0170)
CV Productivity$_{i,c}$	0.0027	0.0026	0.0077	0.0087	0.0022	0.0023	0.0076	0.0086
	(0.0043)	(0.0045)	(0.0075)	(0.0072)	(0.0043)	(0.0044)	(0.0076)	(0.0073)
IO$_{i,j}$					0.7577	0.7014	1.2319*	1.4868**
					(0.4804)	(0.4872)	(0.7317)	(0.7155)
Input FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Output FE	No	No	Yes	Yes	No	No	Yes	Yes
Country FE	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Plant controls	No	No	No	Yes	No	No	No	Yes
Firm controls	No	No	No	Yes	No	No	No	Yes
Noise controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,928	2,928	2,928	2,928	2,889	2,889	2,889	2,889

Notes: The dependent variable is *Delegation*$_{f,p,i,j,c}$, the degree of autonomy granted to plant p (with primary activity i, located in country c) by the parent firm f (with primary activity j). *Mean Productivity*$_{i,c}$ is the mean of supplier productivity. *CV Productivity*$_{i,c}$ is the coefficient of variation of labor productivity of the independent suppliers in input industry i located in country c. *IO*$_{i,j}$ is the direct requirement coefficient for the sector pair ij. Plant-level controls include the percentage of the plant's employees with a bachelor's degree or higher and the plant's share of the firm's employment. Firm-level controls include the employment and age of the parent firm. Output and input fixed effects defined at 4-digit SIC. Standard errors clustered at the input level in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels.

Table A-13

Delegation and uncertainty (winsorizing supplier productivity)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mean Productivity$_{i,c}$	0.0478***	0.0463***	0.0590***	0.0674***	0.0475***	0.0479***	0.0601***	0.0686***
	(0.0139)	(0.0116)	(0.0132)	(0.0132)	(0.0099)	(0.0114)	(0.0131)	(0.0129)
CV Productivity$_{i,c}$	0.0106	0.0427	0.0370	0.0291	-0.0048	0.0270	0.0187	0.0120
	(0.0778)	(0.0488)	(0.0518)	(0.0516)	(0.0494)	(0.0504)	(0.0530)	(0.0529)
IO$_{i,j}$					1.0175***	0.9951**	1.1585**	1.2442***
					(0.3940)	(0.3945)	(0.4691)	(0.4607)
Input FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Output FE	No	No	Yes	Yes	No	No	Yes	Yes
Country FE	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Plant controls	No	No	No	Yes	No	No	No	Yes
Firm controls	No	No	No	Yes	No	No	No	Yes
Noise controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,928	2,928	2,928	2,928	2,889	2,889	2,889	2,889

Notes: The dependent variable is *Delegation*$_{f,p,i,j,c}$, the degree of autonomy granted to plant p (with primary activity i, located in country c) by the parent firm f (with primary activity j). *Mean Productivity*$_{i,c}$ is the mean of supplier productivity. *CV Productivity*$_{i,c}$ is the coefficient of variation of labor productivity of the independent suppliers in input industry i located in country c. *IO*$_{i,j}$ is the direct requirement coefficient for the sector pair ij. Plant-level controls include the percentage of the plant's employees with a bachelor's degree or higher and the plant's share of the firm's employment. Firm-level controls include the employment and age of the parent firm. Output and input fixed effects defined at 4-digit SIC. Standard errors clustered at the input level in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels.

Table A-14

Integration and uncertainty (4-digits SIC industry FE)

	(1)	(2)	(3)	(4)	(5)	(6)
Mean Productivity$_{i,c}$	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
CV Productivity$_{i,c}$	0.0004***	0.0005***	0.0005***	0.0005***	0.0005***	0.0005***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
IO$_{i,j}$			0.1533***	0.2125***	0.2125***	0.2117***
			(0.0130)	(0.0153)	(0.0153)	(0.0153)
Input FE	Yes	Yes	Yes	Yes	Yes	Yes
Output FE	No	No	No	Yes	Yes	-
Country FE	No	Yes	Yes	Yes	Yes	-
Firm FE	No	No	No	No	No	Yes
Firm controls	No	No	No	No	Yes	No
Observations	6,644,884	6,644,884	6,644,884	6,644,884	6,644,884	6,644,884

Notes: The dependent variable is *Integration*$_{f,j,i,c}$, a dummy equal to 1 if firm f producing final product j (defined at 4-digit SIC) and located in country c integrates input i (defined at 4-digit SIC) within its boundaries. *Mean Productivity*$_{i,c}$ is the mean of supplier productivity. *CV Productivity*$_{i,c}$ is the coefficient of variation of labor productivity of the independent suppliers in input industry i located in country c. *IO*$_{i,j}$ is the direct requirement coefficient for the sector pair ij. Firm-level controls include the employment and age of the parent firm. Output and input fixed effects defined at 4-digit SIC. In the specification in column 6, country and output-industry fixed effects are absorbed by the firm fixed effects (each firm f is associated to one location and one primary activity). Standard errors clustered at the input level in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels.

Table A-15

Integration and uncertainty (winsorizing supplier productivity)

	(1)	(2)	(3)	(4)	(5)	(6)
Mean Productivity$_{i,c}$	-0.0003	-0.0134***	-0.0136***	-0.0137***	-0.0137***	-0.0139***
	(0.0032)	(0.0040)	(0.0040)	(0.0040)	(0.0040)	(0.0040)
CV Productivity$_{i,c}$	0.0041**	0.0066***	0.0066***	0.0066***	0.0066***	0.0066***
	(0.0016)	(0.0018)	(0.0018)	(0.0018)	(0.0018)	(0.0018)
IO$_{i,j}$			0.1512***	0.1817***	0.1815***	0.2068***
			(0.0136)	(0.0148)	(0.0148)	(0.0165)
Input FE	Yes	Yes	Yes	Yes	Yes	Yes
Output FE	No	No	No	Yes	Yes	-
Country FE	No	Yes	Yes	Yes	Yes	-
Firm FE	No	No	No	No	No	Yes
Firm controls	No	No	No	No	Yes	No
Observations	5,484,936	5,484,936	5,484,936	5,484,936	5,484,936	5,484,936

Notes: The dependent variable is *Integration*$_{f,j,i,c}$, a dummy equal to 1 if firm f producing final product j (defined at 4-digit SIC) and located in country c integrates input i (defined at 4-digit SIC) within its boundaries. *Mean Productivity*$_{i,c}$ is the mean of supplier productivity. *CV Productivity*$_{i,c}$ is the coefficient of variation of labor productivity of the independent suppliers in input industry i located in country c. *IO*$_{i,j}$ is the direct requirement coefficient for the sector pair ij. Firm-level controls include the employment and age of the parent firm. Output and input fixed effects defined at 3-digit SIC. In the specification in column 6, country and output-industry fixed effects are absorbed by the firm fixed effects (each firm f is associated to one location and one primary activity). Standard errors clustered at the input level in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels.

Table A-16

Integration and uncertainty (single-plant firms)

	(1)	(2)	(3)	(4)	(5)	(6)
Mean Productivity$_{i,c}$	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
	(0.00001)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
CV Productivity$_{i,c}$	0.0006***	0.0007***	0.0007***	0.0007***	0.0007***	0.0007***
	(0.00008)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
IO$_{i,j}$			0.1439***	0.1715***	0.1715***	0.1943***
			(0.0137)	(0.0148)	(0.0148)	(0.0165)
Input FE	Yes	Yes	Yes	Yes	Yes	Yes
Output FE	No	No	No	Yes	Yes	-
Country FE	No	Yes	Yes	Yes	Yes	-
Firm FE	No	No	No	No	No	Yes
Firm controls	No	No	No	No	Yes	No
Observations	6,027,632	6,027,632	6,027,632	6,027,632	6,027,632	6,027,632

Notes: The dependent variable is *Integration*$_{f,j,i,c}$, a dummy equal to 1 if firm f producing final product j (defined at 4-digit SIC) and located in country c integrates input i (defined at 4-digit SIC) within its boundaries. *Mean Productivity*$_{i,c}$ is the mean of supplier productivity. *CV Productivity*$_{i,c}$ is the coefficient of variation of labor productivity of the independent suppliers in input industry i located in country c. *IO*$_{i,j}$ is the direct requirement coefficient for the sector pair ij. Firm-level controls include the employment and age of the parent firm. Output and input fixed effects defined at 3-digit SIC. In the specification in column 6, country and output-industry fixed effects are absorbed by the firm fixed effects (each firm f is associated to one location and one primary activity). Standard errors clustered at the input level in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels.

Table A-17

Integration and uncertainty (matched sample)

	(1)	(2)	(3)	(4)	(5)	(6)
Mean Productivity$_{i,c}$	-0.0000**	-0.0000**	-0.0031**	-0.0000*	-0.0000**	-0.0000**
	(0.000001)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
CV Productivity$_{i,c}$	0.0006***	0.0006***	0.0006***	0.0006***	0.0006***	0.0006***
	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0002)
IO$_{i,j}$			0.0770***	0.1263***	0.1283***	0.1375***
			(0.0120)	(0.0150)	(0.0149)	(0.0159)
Input FE	Yes	Yes	Yes	Yes	Yes	Yes
Output FE	No	No	No	Yes	Yes	-
Country FE	No	Yes	Yes	Yes	Yes	-
Firm FE	No	No	No	No	No	Yes
Firm controls	No	No	No	No	Yes	No
Observations	249,471	249,471	249,471	249,471	249,471	249,471

Notes: The dependent variable is *Integration*$_{f,j,i,c}$, a dummy equal to 1 if firm f producing final product j (defined at 4-digit SIC) and located in country c integrates input i (defined at 4-digit SIC) within its boundaries. *Mean Productivity*$_{i,c}$ is the mean of supplier productivity. *CV Productivity*$_{i,c}$ is the coefficient of variation of labor productivity of the independent suppliers in input industry i located in country c. *IO*$_{i,j}$ is the direct requirement coefficient for the sector pair ij. Firm-level controls include the employment and age of the parent firm. Output and input fixed effects defined at 3-digit SIC. In the specification in column 5, country and output-industry fixed effects are absorbed by the firm fixed effects (each firm f is associated to one location and one primary activity). Standard errors clustered at the input level in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels.

Table A-18

Integration and uncertainty (50+ suppliers per input sector)

	(1)	(2)	(3)	(4)	(5)	(6)
Mean Productivity$_{i,c}$	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
CV Productivity$_{i,c}$	0.0005***	0.0007***	0.0007***	0.0007***	0.0007***	0.0007***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
IO$_{i,j}$			0.1602***	0.1978***	0.1977***	0.2293***
			(0.0163)	(0.0178)	(0.0178)	(0.0203)
Input FE	Yes	Yes	Yes	Yes	Yes	Yes
Output FE	No	No	No	Yes	Yes	-
Country FE	No	Yes	Yes	Yes	Yes	-
Firm FE	No	No	No	No	No	Yes
Firm controls	No	No	No	No	Yes	No
Observations	5,484,936	5,484,936	5,484,936	5,484,936	5,484,936	5,484,936

Notes: The dependent variable is *Integration*$_{f,j,i,c}$, a dummy equal to 1 if firm f producing final product j (defined at 4-digit SIC) and located in country c integrates input i (defined at 4-digit SIC) within its boundaries. *Mean Productivity*$_{i,c}$ is the mean of supplier productivity. *CV Productivity*$_{i,c}$ is the coefficient of variation of labor productivity of the independent suppliers in input industry i located in country c. *IO*$_{i,j}$ is the direct requirement coefficient for the sector pair ij. Firm-level controls include the employment and age of the parent firm. Output and input fixed effects defined at 3-digit SIC. In the specification in column 6, country and output-industry fixed effects are absorbed by the firm fixed effects (each firm f is associated to one location and one primary activity). Standard errors clustered at the input level in parentheses. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels.