All Together Now: Integration, Decentralization and Management

PRELIMINARY – PLEASE DO NOT CIRCULATE

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1 Introduction

There is growing evidence that firm organization matters for the performance of aggregate economies (e.g. Hsieh and Klenow, 2009; Alfaro, Charlton, and Kanczuk 2009; Bloom, Sadun and Van Reenen, 2012, 2015). Yet, the economics of firm organization is rather strangely split into two stark divisions (Gibbons and Roberts, 2013). On the one hand there are theories on what determines the boundary of the firm (the 'make or buy decision') and on the other hand a concern with how a firm organizes itself internally, for example in the degree of decentralization. Despite these intellectual silos the decisions over whether to integrate and to decentralize are both endogenous choices and could be dependent, suggesting that a common analysis is necessary.

Organizational design is not so much figuring out the right decision, but deciding who should make it. But this right to delegate is in the hands of owners, and therefore the possibility of delegation depends on the integration decision. Consider the classic supplier-producer relationship between a car part maker (supplier) and an auto manufacturer (final goods producer). If the parties are vertically integrated in a single firm there is still a decision to be made of whether to delegate decision making on tailoring a car part to the particular model of car produced. If the firms are trading at arms-length, then (outside of a very complex contract) there is little possibility of delegation. Thus, delegation is limited by the firm's boundaries. At the same time, the possibility of achieving decentralization via delegation inside the firm softens the rigidities that Coase (1937) famously cited as among the costs of managerial authority: integration and delegation may therefore be complements.

Previous work whether theoretical or empirical have tended to study the integration and internal organization decisions separately (among the few exceptions on the theoretical side are Hart and Holmström, 2010, Legros and Newman 2015 and Powell 2015), even if in many models, non-integration could be regarded as the corner case of complete decentralization in an integrated firm. For the first time, to our knowledge, we bring these two strands together empirically. To do so, we operationalize the theoretical framework developed in Legros and Newman (2015) to analyze how the integration and decentralization decisions take place and what factors may determine this. We then assemble a new dataset that contains survey information on decentralization (based on updated data from Bloom, Sadun and Van Reenen, 2012) and structural information from firm accounts on vertical integration (based on updated data from Alfaro et al, 2016). Again, to our knowledge, this is the first time that data of this type has been combined, at least for a sample with many thousands of firms covering multiple industries and countries. This data constraint has long been recognized as a reason for the slow development of the field of organizational economics.

A related and relatively recent strand of the literature (e.g. Bloom, Sadun and Van Reenen, 2015) has sought to systematically measure *management practices* most likely to improve productivity (e.g. monitoring, targets and incentives) across multiple firms in different countries. Although these management measures seem to be very informative in explaining micro and macro economic performance, there remains the question of how we should theoretically understand their relationship to the integration and delegation decisions of the firm. Another contribution of the paper is to bring management into the theory and empirical framework we develop.

To tackle these issues we develop a tractable theoretical model in which a producer and its suppliers choose their degree of integration and how much to invest in management practices. Once the integration choices are made, the management of the firm will decide to decentralize decision making to the (integrated) suppliers or not. In our model, final good producers are *ex-ante* uncertain about the ability of suppliers to customize their input to the (specific) production needs of the manufacturer. Supplying an intermediate good (e.g. a car part like a seat or engine component) requires some adaptation/customization for the final product (e.g. the car seats for a Mercedes are different than for a Prius). The manufacturer may have a comparative advantage in customization, something that is learned *after* the integration decision has been made, but his interests may not coincide with that of the manufacturer. If the transaction is arms length, the adaptation is done by the final goods producer. This still might happen if the manufacturer and the supplier integrate, but at least after integration there is the option of delegating to the supplier to do the adaptation. Hence, as in Legros and Newman (2015) integrating these suppliers has an *option value*, i.e. it allows the final good producer to choose whether or not to delegate decisions to the suppliers or to keep control. Investing in management is a way of increasing the probability that the supplier does the customization well instead of following his own agenda. In our model, investments in management are costly, but they have the advantage of better monitoring the delegated decisions (i.e. checking that the suppliers do not just pursue private benefits).

The model produces several intuitive predictions. First, we show that integration, decentralization and management all covary positively. This is because final good manufacturers that are high productivity (the exogenous primitive of the model) are able to provide more surplus in a relationship with a supplier and will therefore integrate more suppliers. Higher productivity also gives a greater incentive to invest in management to make sure the delegation is successful, something that increases also total surplus. In other words, our model naturally generates complementarity between management, decentralization and integration.

Note that the causality flows here from higher productivity of the manufacturer to integration, delegation and management.

A second prediction of the model is that the positive relationship between the degree of decentralization and vertical integration is mediated through management. Hence, conditional on management there should be no effect of integration on decentralization. This sharp result is because the correlation between integration and productivity is direct, whereas the relationship between decentralization and integration is indirect (it works through the incentive to invest in management).

A third prediction is that suppliers who integrate have an ability to customize that is riskier than the suppliers who do not integrate. Indeed, as we have already noted integration in our model creates a real option (to delegate or not), and the greater the risk about the ability of the supplier to do the customization, the more valuable the option becomes. Thus, the model predicts that integration is more likely when suppliers' productivity is more dispersed.

We show that the three sets of predictions of the theoretical model are remarkably consistent with the features of the new international firm-level data we have put together. They hold up whichever sample we use and whatever robustness tests we employ. We argue that our model is a more plausible interpretation of the patterns we observe than competing theories. Hence, we see our model as a useful approach to combining the disparate strands of the theoretical and empirical literature.

In terms of the existing literature, there is a vast amount of work on the boundaries of the firm. Theoretical studies have looked at inter alia the technological/contractual determinants of vertical integration (e.g. Coase 1937; Williamson 1975; Grossman and Hart 1986; Holmström and Milgrom, 1991; Hart and Holmström, 2010). Another strand has focused on market determinants (e.g. McLaren 2000; Grossman and Helpman 2002; Legros and Newman, 2008, 2013; Conconi *et al.*, 2012). Empirical studies have tried to shed light on these determinants using firm-level data within specific industries (e.g. Joskow, 1987; Baker and Hubbard, 2003; Woodruff, 2002; Hortaçsu and Syverson, 2007), countries (e.g. Acemoglu, Aghion, Griffith and Zilibotti, 2010), or across countries (e.g. Acemoglu, Johnson and Mitton, 2009; Alfaro, Conconi, Fadinger and Newman, 2016; Alfaro and Charlton, 2009). Recent work studies integration decisions along value chains (Antràs and Chor, 2013; Alfaro, Antràs, Conconi, and Chor, 2015).

Looking at the literature on decentralization, we relate to some classic theoretical studies including Aghion and Tirole (1997), Garicano (2000), Dessein (2002), Hart and Moore (2005), Alonso, Dessein and Matouschek (2008), Marin and Verdier (2008). On the empirical side our work is related to Acemoglu et al (2007), Guadalupe and Wulf (2011), Bloom, Garicano, Sadun and Van Reenen (2013) and Bloom, Sadun and Van Reenen (2012). Finally, work on management practices includes Gibbons and Roberts (2013), Woodward,(1958), Bloom and Van Reenen (2007), Bloom, Eifert, Mahajan, McKenzie, and Roberts (2013); Bloom, Sadun and Van Reenen (2015).

Throughout the paper we assume contracts are incomplete so the problems cannot be simply designed away with contracting. This is a stark assumption, but real world contracts are highly incomplete. Even with some second best contracts the organizational effects we study here will still be at play to some extent.

The structure of the paper is as follows. Section 2 details the theory, Section 3 the data and Section 4 the empirical results. We offer some concluding comments in Section 5.

2 The model

We describe a simple model in which a final good producer chooses which suppliers to integrate, whether to delegate decisions to integrated suppliers, and which management practice to adopt.

- The final good j producer has exogenous productivity $2A$.
- Production of j requires inputs $i \in [0, 1]$.
- Suppliers $i \in [0, 1]$ produce generic inputs. Each input i has to be adapted to the specialized production process of good j, and the final expected output depends on who makes the adaptation (see below).
- Whether the input is adapted to the specialized production process is neither verifiable nor contractible.
- Suppliers $i \in [0, 1]$ are characterized by distributions $F_i(y)$, where y is their comparative advantage/productivity at generating the input.
- Management M disciplines integrated suppliers who are delegated production decisions (by providing good business practices, monitoring, avoiding wasteful use of resources, improving logistics, etc.). To simplify, we assume that management cannot be tailored to the characteristics of individual suppliers; M is the "management practice" or "management style" of the producer. Putting in place this internal organization requires a cost $c(M)$, e.g., salaries of managers, computer systems for monitoring activity, etc.

- Timing: HQ (could be the final good producer but could be also an outsider) chooses which suppliers to integrate and which management practice M to adopt. After the transfer of ownership, HQ learns the productivity of the supplier.
- The final expected output depends on who makes the adaptation of the input.
  - If the producer makes the adaptation decision — which happens if the supplier is not integrated or if it is integrated but there is no delegation — the probability of success is $\frac{1}{2}$. Expected output in this case is A (there is a probability of $1/2$ of success and output is $2A$).
  - If the supplier is integrated and is delegated the task to adapt the input to the specialized production process, he is constrained by management. In this case, the probability of success is $\frac{My_i}{2}$ and expected output is AMy_i. My_i can be greater or smaller than 1, reflecting the comparative advantage/relative productivity of the supplier of adapting the input to the specialized production process.
  - The interpretation is that M reflects how effective the final producer is at getting *other* folks to produce, i.e. how effective at overcoming 'agency problems.' When he does things himself, agency doesn't enter, and his output is normalized to 1.

Consider an integrated structure with management style M.

- If there is centralization of decisions, expected output is A.
- If instead there is delegation, the supplier has (temporary) control of the production process. HQ prefers to delegate if expected output is larger when the supplier decides, that is when $My_i > 1$.

Hence, under integration and management M, the probability of delegation is equal to the probability that y_i is greater than $\frac{1}{M}$, that is $1 - F_i(1/M)$, which is an increasing function of M. This is our first result:

Result 1. *The probability of delegation increases with better management practices (higher M).*

Expected output from using input i is equal to $AQ_i(M)$ where[1]

$$\begin{aligned} Q(i;M) &:= \mathcal{E}_i \max(1, My) \\ &= F_i(1/M) + \int_{y \geq 1/M} (My_i) dF_i(y_i). \end{aligned}$$

This function $Q(i, M)$ reflects the value of an option, namely the option for the final producer (or HQ) to delegate decision rights after integration.

Remember that the producer bears an organizational cost of $c(M)$, increasing in M and normalized to $c(0) = 0$ while each supplier who is integrated bears a private cost of ϕ.[2]

The welfare when supplier i is integrated with producer j who uses management practice M is then:

$$\omega(i, M; A) := AQ(i, M) - \phi.$$

Without loss of generality, let the indices for suppliers be ordered in such a way that $Q(i, M)$ is a decreasing function of i. It follows that the surplus function $\omega(i, M; A)$ is a decreasing function of i, and that if there is a measure I of suppliers who are integrated, it is surplus maximizing to integrate the suppliers with index $i \leq I$.

Hence if the producer uses management practice M, total welfare when I suppliers are integrated is equal to

$$W(I, M; A) = \int_0^I \omega(i, M; A) di + (1 - I)A - c(M).$$

The variations of total surplus with respect to I, M are:

$$W_I = A(Q(I, M) - 1) - \phi = 0 \tag{1}$$

$$W_M = \int_0^I AQ_M(i, M) di - c'(M) = 0, \tag{2}$$

where

$$Q_M(i, M) = \int_{y_i \geq 1/M} y dF_i(y_i),$$

[1] Obviously there are conditions on the support of y such a way that My is between $0, 2$ for any value of M.

[2] In a more general model, this cost ϕ may differ when there is delegation, from what it is under centralization, and may also be a function of M. Our assumption that the private cost is of the probability of delegation, allows us to generate a clear-cut prediction for the role of riskiness, our last prediction.

is positive. Hence,

$$W_{IA} = Q(I, M) - 1 > 0$$
$$W_{MA} = \int_0^I Q_M(i, M) > 0$$
$$W_{IM} = AQ_M(I, M) > 0.$$

Hence, total surplus is supermodular in $(A, I$, (A, M) and (I, M). It follows that the solution $(I(A), M(A)) = \arg\max_{I\in[0,1],M} W_j(I, M)$, is increasing in A.

Result 2. *More productive producers integrate more suppliers and use better management practices.*

This result is cast in the special case of an ordering on the set of suppliers corresponding to a (decreasing) second order stochastic ordering of the distributions F_i. Since $\max(1, My)$ is a convex and increasing function of y, for two suppliers $i, \hat{i}$ such that F_i is dominated in the second order by $F_{\hat{i}}$, the option values are ordered: for any M, $Q_i(M) > Q_{\hat{i}}(M)$. Therefore $Q_i(M)$ is a decreasing function of i; since we have already shown that in this case the integrated suppliers are those with the largest values of $Q_i(M)$, we have:

Result 3. *The final good producer is more likely to integrate suppliers for which the distribution of y is riskier in the second order stochastic sense.*

Extension of model to develop testable predictions about firm age. We will assume that firms have an imperfect ability to learn the productivity of integrated suppliers and derive predictions about the role of **firm age** (see predictions P.4-P.6).

The broad idea is that older firms have more experience in identifying their comparative advantage over suppliers. Take two extreme cases:

> For young firms, which cannot identify their comparative advantage vis-à-vis suppliers, integration is based only on the expected value of y. For this firms, there is no option value of integration.
>
> Old firms, which can identify their comparative advantage vis-à-vis input suppliers, are those in the current model, in which integration is a function of the CV.

Thus older firms should be more likely to delegate riskier suppliers.

2.1 Testable predictions

Our simple theoretical model yields several testable predictions about firms' integration and delegation decisions.

Result 1 implies that

> Prediction P.1: Delegation and management practices should be positively correlated at the firm level.

Result 2 shows that integration and delegation decision covary positively with A, the productivity of the final good producer. More productive producers can use better management techniques, that will eventually lead to more delegation since $1/M$ is a decreasing function of M, but can also more easily compensate suppliers for their private loss of control cost $c(M)$, hence can integrate more suppliers.

> Prediction P.2: Vertical integration and delegation should be positively correlated at the firm level. The positive correlation should disappear by controlling for management practices (M).

The intuition behind this prediction is simple. Both integration and delegation decision depend on A, the productivity of the final good producer. A has a *direct* effect on integration decisions: more productive producers integrate more. By contrast, A has only an *indirect* effect on delegation decisions, though its effect on M. If we regress firm-level measure of delegation on firm-level measures of integration without controlling for productivity and management practices, we should thus observe a positive correlation between them. The link between integration and delegation decisions should instead disappear if we control for firms' management practices.

Result 3 yields a third testable prediction, since it shows that uncertainty in the productivity of suppliers increases the option value of integration, making "riskier" suppliers more likely to be integrated. In particular, if the distributions $F_i(y)$, are log-normal, $y = e^{\mu_i + \sigma x}$ where $x \sim N(0,1)$. The mean is equal to $m_i = e^{\mu_i + \frac{\sigma^2}{2}}$, the variance is equal to $(e^{\sigma^2} - 1)m_i^2$ and the coefficient of variation is $CV_i = \sqrt{e^{\sigma^2} - 1}$. It is known (Levy, 1973) that F_i dominates F_j in the second order stochastic sense if whenever $m_i = m_j$, $CV_i > CV_j$.

> Prediction P.3: If suppliers' productivity follows a log-normal distribution, controlling for the mean productivity, final good producers are more likely to integrate input suppliers with a larger coefficient of variation of productivity.

Note that testing Prediction P.3 does not require information on firm-level delegation. All we need is information on the integration decisions of final good producers and on the distribution of productivity of their input suppliers.

The theory extension about age, wherein the ability to exercise the option increases with ages, leads to additional predictions:

> Prediction P.4: Greater uncertainty in the productivity of input suppliers has a larger impact on integration decisions of older firms.

3 Dataset and Variables

To carry out our empirical analysis, we construct a unique dataset combining firm-level information on vertical integration, delegation, and management practices.

In what follows, we describe the data on each of these organizational variables.

3.1 Data on vertical integration

To measure vertical integration, we follow Alfaro *et al.* (2016), combining information from on firms' production activities Dun & Bradstreet's WorldBase with input-output data.

WorldBase is a database covering public and private companies in more than 200 countries and territories.[3] The unit of observation is the establishment/plant. With a full sample, plants belonging to the same firm can be linked via information on domestic and global parents using the DUNS numbers.[4]

The WorldBase dataset has been used extensively in the literature (e.g. Alfaro and Charlton, 2009; Acemoglu, Johnson and Mitton, 2009; Fajgelbaum, Grossman and Helpman, 2015; Alfaro, Antràs, Chor, and Conconi, 2015; Alfaro, Conconi, Fadinger, and Newman 2016). One of the advantages of WorldBase compared to other international datasets is that it

[3] WorldBase is the core database with which D&B populates its commercial data products, including Who Owns Whom™, Risk Management Solutions™, Sales & Marketing Solutions™, and Supply Management Solutions™. These products 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. For more information see: http://www.dnb.com/us/about/db_database/dnbinfoquality.html.

[4] D&B uses the United States Government Department of Commerce, Office of Management and Budget, Standard Industrial Classification Manual 1987 edition to classify business establishments. The Data Universal Numbering System — the D&B DUNS Number — introduced in 1963 to identify businesses numerically for data-processing purposes, supports the linking of plants and firms across countries and tracking of plants' histories including name changes.

is compiled from a large number of sources (e.g. partner firms, telephone directory records, websites, self-registration). Admittedly, sample coverage may vary across countries, but this problem can be mitigated by focusing on manufacturing firms above a size threshold of employees (see discussion below).[5]

Our main sample is based on the 2005 WorldBase dataset. As mentioned above, the unit of observation in WorldBase is the establishment/plant, a single physical location at which business is conducted or services or industrial operations are performed.

For each establishment, we use different categories of data recorded in WorldBase:

1. Industry information: the 4-digit SIC code of the primary industry in which each establishment operates, and the SIC codes of as many as five secondary industries.

2. Ownership information: information about the firms' family members (number of family members, domestic parent and global parent).[6]

3. Location information: country, state, city, and street address of each plant.

4. Basic operational information: sales and employment.

5. Information on the trade status (exporting/non-exporting).

We carry out the analysis at the firm level, using DUNS numbers to link plants that have the same ultimate owner.

We focus on manufacturing firms (i.e. firms with a primary SIC code between 2000 and 3999). We exclude firms that do not report their primary activity, government/public sector firms, firms in the service, and agriculture sectors, and firms producing primary commodities (i.e. mining and oil and gas extraction).

We further exclude firms with less than 20 employees, as our theory is less apt to apply to self-employment or small firms with little prospect of vertical integration. Restricting the analysis to firms with more than 20 employees also enables us to correct for possible differences in the collection of data on small firms across countries (see Klapper, Laeven, and Rajan, 2006).

Constructing measures of vertical integration is highly demanding in terms of data, requiring firm-level information on sales and purchases of inputs by various subsidiaries of a

[5]See Alfaro and Charlton (2009) for a more detailed discussion of the WorldBase data and comparisons with other data sources.

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

firm. Such data are generally not directly available and, to the best of our knowledge, there is no source for such data for a wide sample of countries.

To measure the extent of vertical integration for a given firm, we build on the methodology developed by Fan and Lang (2000). We combine information on plant activities and ownership structure from WorldBase with input-output data to construct the index $V_{f,k,c}$, which measures the degree of vertical integration of firm *f*, with primary sector *k*, located in country c. Given the difficulty of finding input-output matrices for all the countries in our dataset, we follow Acemoglu, Johnson and Mitton (2009) and Alfaro and Charlton (2009) in using the U.S. input-output tables to provide a standardized measure of input requirements for each sector. As the authors note, the U.S. input-output tables should be informative about input flows across industries to the extent that these are determined by technology.[7]

The input-output data are from the Bureau of Economic Analysis (BEA), Benchmark IO Tables, which include the make table, use table, and direct and total requirements coefficients tables. We use the Use of Commodities by Industries after Redefinitions 1992 (Producers' Prices) tables.[8]

For every pair of industries, i, j, the input-output accounts provide the dollar value of i required to produce a dollar's worth of j. By combining information from WorldBase on firms' activities with U.S. input-output data, we construct the input-output coefficients for each firm f, IO^f_{ij}. Here, $IO^f_{ij} \equiv IO_{ij} * I^f_{ij}$, where IO_{ij} is the input-output coefficient for the sector pair ij, stating the dollars of output of sector i required to produce a dollar of j, and $I^f_{ij} \in \{0, 1\}$ is an indicator variable that equals one if and only if firm f owns plants in both sectors i and j. A firm that produces i as well as j will be assumed to supply itself with all the i it needs to produce j; thus, the higher IO_{ij} for an i-producing plant owned by the firm, the more integrated in the production of j the firm will be measured to be.

The firm's integration index in activity j is

$$V^j_{f,k,c} = \sum_i IO^{f,k}_{ij}, \tag{3}$$

[7]Note that the assumption that the U.S. IO structure carries over to other countries can potentially bias our empirical analysis against finding a significant relationship between vertical integration and prices by introducing measurement error in the dependent variable of our regressions. In addition, using the U.S. input-output tables to construct vertical integration indices for other countries mitigates the possibility that the IO structure and control variables are endogenous.

[8]While the BEA employs six-digit input-output industry codes, WorldBase uses the SIC industry classification. The BEA website provides a concordance guide, but it is not a one-to-one key. For codes for which the match was not one-to-one, we randomized between possible matches in order not to overstate vertical linkages. The multiple matching problem, however, is not particularly relevant when looking at plants operating only in the manufacturing sector (for which the key is almost one-to-one).

the sum of the IO coefficients for each industry in which the firm is active. Our measure of vertical integration is based on the firm's primary activity:

$$V_{f,k,c} = V^{j}_{f,k,c}, j = k. \tag{4}$$

In the case of multi-plant firms, we link the activities of all plants that report to the same headquarters and consider the main activity of the headquarters as the primary sector.

As an illustration of the procedure used to construct the vertical integration index, consider an example, taken from Alfaro, Conconi, Fadinger, and Newman (2016), of a Japanese shipbuilder that has two secondary manufacturing activities, Fabricated Metal Structures (SIC 3441/BEA IO code 40.0400) and Sheet Metal Work (3444/40.0700).[9] The IO_{ij} coefficients for these sectors are:

		Output (j)
		Ships
Input (i)	*Ships*	0.0012
	Fab. Metal	0.0281
	Sheet Metal	0.0001

This table is just the economy-wide IO table's output column for the firm's primary industry, Ship Building and Repairing (3731/61.0100), restricted to the input rows for the industries in which it is active. The IO_{ij} coefficient for fabricated metal structures to ships is 0.0281, indicating that 2.8 cents worth of metal structures are required to produce a dollar's worth of ships. The firm is treated as self-sufficient in the listed inputs but not any others, so its vertical integration index $V_{f,k,c}$ is the sum of these coefficients, 0.0294: about 2.9 cents worth of the inputs required to make a dollar of primary output can be produced within the firm.[10]

It is important to stress that any potential misclassification of integrated versus non-integrated inputs would give rise to measurement error in the dependent variable in our regressions (when we assess the validity of predictions P.3-P.5). To the extent that this is classical measurement error, it would make our coefficient estimates less precise, making it harder to find empirical support for the model's predictions. In robustness checks we show that our results are robust to restricting the analysis to single establishment firms, for which the Fan and Lang (2000) is less likely to give rise to measurement error.

[9]There is no concern about right censoring in the number of reported activities: only 0.94 percent of establishments with primary activity in a manufacturing sector report the maximum number of five secondary activities.

[10]Many industries, including Ship Building and Repairing, have positive IO_{jj} coefficients with themselves. Any firm that produces such a product will therefore be measured as at least somewhat vertically integrated.

3.2 Data on decentralization

- Survey of 8000 manufacturing firms in 20 countries

- **Plant managers** were asked questions about how many **decisions** they can make **without HQ intervention**:

  - Hiring
  - Budgeting
  - Sales and marketing
  - Product introduction

- Individual measures for each category (5 point scale) aggregated into an **overall decentralization index**.

3.3 Data on management practices

To measure management practices (A in the model), we use the management evaluation score developed in Bloom and Van Reenen (2007) and extended in Bloom, Sadun and Van Reenen (2014). They collect information on 18 dimensions of firms' management grouped into three areas: (A) performance monitoring (information collection and analysis); (B) effective targets (using stretching short and long run targets); and (C) performance incentives (rewarding high-performing employees, and retraining or moving underperformers). The 18 individual management dimensions are averaged into one overall management score after they have each been normalized to z-scores (a mean of zero and a standard-deviation of one).

WE CAN MENTION THAT THE RESULTS ARE ROBUST TO DROPPING COMPONENT (C) FROM THE Z SCORES (COMPOMENENTS (A) AND (B) FIT BETTER WITH THE INTERPRETATION OF MANAGEMENT PRACTICES M IN OUR MODEL).

3.4 Samples

To verify predictions P.1 and P.2, we have matched 3444 firms in 19 countries for which we observe both the degree of vertical integration and the degree of decentralization.[11] WE

[11]The data is contracted using plant-level data. For the decentralization index, we usually observe only one plant per firm (and if more than one plant, all have the same delegation z-score).

SHOULD PROVIDE MORE INFORMATION ON HOW WE DID THE MATCHING OF FIRMS (POSSIBLY IN AN APPENDIX). Table A-1 presents summary statistics for all the variables used in the regressions based on this sample.

To verify predictions P.3-P.5, we do not need data on delegation and management, so we can use the larger sample of firms from Alfaro *et al.* (2016). We restrict the analysis to firms located in those 19 countries for which we have information on delegation and management practices for at least some firms. Table A-2 presents summary statistics for all the variables used in the regressions based on this sample.

4 Empirical results

4.1 Relationship between integration and delegation

To verify prediction P.1, we regress the overall decentralization index of firm f producing final good j and located in country c against the firm's management score:

$$\text{Decentralization}_{fjc} = \alpha_0 + \alpha_1 \text{ Management score}_f + \alpha_2 \mathbf{X}_f + \delta_j + \delta_c + \epsilon_{fjc}, \quad (5)$$

where $\mathbf{X}_f$ is a matrix of firm-level controls and δ_j and δ_c are output industry and country fixed effects.[12] According to prediction P.1, the coefficient α_1 should be positive and significant.

[12]Given that the information about delegation decisions was collected in different waves, we also include fixed effects for the year in which the firm was surveyed.

Table 1: Delegation and management

	(1)	(2)	(3)
Management score$_f$	**x**	**x**	**x**
	(x)	(x)	(x)
log(Employment$_f$)			x
			(x)
log(1+age$_f$)			x
			(x)
MNC$_f$			x
			(x)
log(% Workforce with a College Degree$_f$)			x
			(x)
Country FE	yes	yes	yes
Output sector FE	no	yes	yes
R-squared	x	x	x
N	x	x	x

Notes: The dependent variable, *Decentralisation*$_{fjc}$, is the overall autonomy index of firm f producing good j in country c.

4.2 Relationship between integration and delegation

To verify prediction P.2, we regress the decentralization index against the vertical integration index:

$$\text{Decentralization}_{fjc} = \beta_0 + \beta_1 \text{ Vertical Integration}_f + \beta_2 \mathbf{X}_f + \delta_j + \delta_c + \epsilon_{fjc}. \qquad (6)$$

According to prediction P.2, the estimated coefficient β_1 should be positive and significant — unless the matrix $\mathbf{X}_{fjc}$ includes for proxies for M in the model, in which case β_1 should not be significant.

Table 2: Delegation, vertical integration and managament

	(1)	(2)	(3)	(4)	(5)	(6)
Vertical Integration$_f$	**x**	**x**	**x**	**x**	**x**	**x**
	(x)	(x)	(x)	(x)	(x)	(x)
Management score$_f$				**x**	**x**	**x**
				(x)	(x)	(x)
log(Employment$_f$)			x			x
log(1+Age$_f$)			x			x
MNC$_f$			x			x
log(% Workforce with a College Degree$_f$)			x			x
Country FE	x	x	x	x	x	x
Output sector FE		x	x		x	x
R-squared	x	x	x	x	x	x
N	x	x	x	x	x	x

Notes: The dependent variable, *Decentralisation*$_{fjc}$, is the overall autonomy index of firm f producing good j in country c.

The results are reported in Table 2. In line with prediction P.2, the estimated coefficient of *Vertical Integration*$_f$ is positive and significant in columns (1)-(3), and becomes insignificant in columns (4)-(5), in which we control for the firm's management practices.

4.3 Option value of integration

According to prediction P.3 of our model, in sectors where there is more uncertainty (in terms of second-order stochastic dominance) about the productivity of upstream plant managers, there should be more vertical integration.

To test this prediction, we regress the probability that firm f producing final product j located in country c integrates input i on the coefficient of variation of the productivity of i suppliers in country c (*CV productivity*$_{ic}$), controlling for the average of labor productivity in sector i (*Mean productivity*$_{ic}$). To construct these variables we use information on labor productivity of firms with primary sector i in country c. In some specifications, we impose a minimum number of suppliers (50) in each country-sector to construct these variables.

Given that the distribution of productivity of input suppliers follows a log-normal distribution, we can assess the validity of prediction by running the following specification:

$$\text{Integration}_{fjic} = \gamma_0 + \gamma_1 \text{ CV Productivity}_{ic} + \gamma_2 \text{ Mean Productivity}_{ic} + D_f + D_i + \epsilon_{fjic} \quad (7)$$

The dependent variable, *INT*$_{ijfc}$, is a 0-1 indicator for whether firm f located in country c with primary output j has integrated input i within its boundaries. The key explanatory variable is *CV Productivity*$_{ic}$, the coefficient of variation of labor productivity of the suppliers in input industry i located in country c. *Mean Productivity*$_{ic}$ is the mean of input suppliers' productivity. D_i and D_f denote input industry and firm fixed effects.[13] We estimate (7) as a linear probability model, with standard errors clustered at the input industry i level. To keep the analysis tractable, we limit the sample to the top 100 inputs i used by j, as ranked by the total requirements coefficient tr_{ij} (see also Antras *et al*., 2015).

This specification allow us to study the integration decisions of individual firms, and how they are affected by uncertainty in the productivity of supplier firms. Our model suggests that this uncertainty gives rise to an option value of integration. According to prediction P.3, the estimated coefficient γ_1 should be positive and significant.

The results of different specifications are reported in Table 3. We include all manufacturing firms in our large sample and consider all the inputs necessary to produce the firm's output (identified by its reported primary SIC code).

In all specifications, the estimated coefficient for *CV Productivity*$_{ic}$ is positive and significant, in line with prediction P.3. This result suggests that, due to the uncertainty in the productivity of suppliers, there is an option value of integrating them.

[13] Country fixed effects are absorbed by the firm fixed effects, since each firm is associated to the location of its headquarters.

The results are robust to restricting the analysis to manufacturing inputs (see Table A-2). They also continue to hold if we focus on the sample of firms in our matched sample (see Table **??**).[14]

To assess the validity of predictions P.4, we estimate

$$\begin{aligned} \text{Integration}_{fjic} &= \theta_0 + \theta_1 \text{ Old}_f + \theta_2 \text{ Old}_f \text{ x CV Productivity}_{ic} + \theta_3 \text{ CV Productivity}_{ic} \\ &\quad + \theta_4 \text{ Mean Productivity}_{ic} + D_i + D_c + \epsilon_{fjic}, \end{aligned} \tag{8}$$

where *Old*$_f$ is a dummy variable equal to 1 is the age of firm f. We expect the coefficient $theta_1$ to be positive and significant.

According to Prediction P.4, the coefficient $theta_2$ should also be positive and significant, reflecting the fact the higher option value of integration for older firms. We can also identify this last prediction including firm fixed effects (D_f) and input sector-country fixed effects (D_{ic}) and dropping the variables *Old*$_f$m *CV Productivity*$_{ic}$ and *Mean Productivity*$_{ic}$:

$$\text{Integration}_{fjic} = \phi_0 + \phi_1 \text{ Old}_f \text{ x CV Productivity}_{ic} + D_f + D_{ic} + \epsilon_{fjic}. \tag{9}$$

This specification allows us to deal with endogeneity concerns, since it allows us to account for any unobservable firm and sector-country characteristics that might be correlated with the integration decision of final good producers and the productivity of input suppliers. Again, according to P.4, we expect the coefficient ϕ_1 to be positive.

[14] Given that sample of firms included in this exercise is now much smaller, we study the decision to integrate the inputs necessary to produce all their outputs (i.e. all the SIC codes reported by the firm, rather than only their primary SIC code).

Table 3: Option value of vertical integration

	(1)	(2)	(3)	(4)	(5)	(6)
CV Productivity$_{ic}$	**0.00028****	**0.00034****	**0.00033****	**0.00023***	**0.00033****	**0.00032****
	(0.00013)	(0.00014)	(0.00014)	(0.00014)	(0.00014)	(0.00014)
Mean Productivity$_{ic}$	-0.00000	-0.00000	-0.00000	-0.00000	-0.00000	-0.00000
	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)
log(Employment$_f$)	0.00236***	0.00277***		0.00278***	0.00322***	
	(0.00019)	(0.00017)		(0.00024)	(0.00021)	
log(1+ Age$_f$)	0.00065***	0.00012		0.00078***	0.00014	
	(0.00019)	(0.00016)		(0.00022)	(0.00018)	
MNC$_f$	0.01242***	0.01154***		0.01284***	0.01205***	
	(0.00127)	(0.00126)		(0.00143)	(0.00141)	
Input sector FE	yes	yes	yes	yes	yes	yes
Country FE	no	yes	no	no	yes	no
Firm FE	no	no	yes	no	no	yes
R-squared	0.040	0.040	0.038	0.041	0.042	0.039
N	6589556	6589556	6589556	5488807	5488807	5488807
Firms	66429	66429	66429	66314	66314	66314

Notes: The dependent variable is *Integration*$_{fijc}$, a dummy variable equal to 1 if firm f located in country c with primary output j integrates input i. Columns (1)-(3) include all input industries i, while columns (4)-(6) includes only industries in which there are less than 50 suppliers to construct the variables *CV Productivity*$_{ic}$ and *Mean Productivity*$_{ic}$. *CV Productivity*$_{ic}$ is the coefficient of variation of labor productivity of the suppliers in input industry i located in country c, while *Mean Productivity*$_{ic}$ is the mean of input suppliers' productivity. *Employment*$_f$ measures total firm employment, *Age*$_f$ is the number of years since the firm's establishment, and *MNC*$_f$ is a dummy variable equal to 1 if the firm has subsidiaries in more than one country.

- The results of Table 3 continue to hold if we

  Restrict the analysis to manufacturing inputs.

  Restrict the analysis to firms in the US (not reported)

  Restrict the analysis to single-plant firms (to deal with concerns about measurement errors in the VI index, based on Atalay *et al.*, 2014) (not reported)

Table 4: Option value of vertical integration (old versus young firms)

	(1)	(2)	(3)	(4)
CV Productivity$_{ic}$ x Old$_f$	**0.00015****	**0.00015****	**0.00015****	**0.00015****
	(0.00007)	(0.00007)	(0.00008)	(0.00007)
CV Productivity$_{ic}$	**0.00028****	**0.00022***	**0.00027****	
	(0.00013)	(0.00013)	(0.00013)	
Mean Productivity$_{ic}$	-0.00000	-0.00000	-0.00000	
	(0.00000)	(0.00000)	(0.00000)	
Mean Productivity$_{ic}$ x Old$_f$	-0.00000	-0.00000	-0.00000	-0.00000
	(0.00000)	(0.00000)	(0.00000)	(0.00000)
Old$_f$	-0.00034	-0.00002		
	(0.00034)	(0.00037)		
log(Employment)$_f$	0.00277***	0.00234***		
	(0.00017)	(0.00019)		
MNC$_f$	0.01154***	0.01252***		
	(0.00126)	(0.00127)		
Input sector FE	yes	yes	yes	no
Country FE	yes	no	no	no
Firm FE	no	no	yes	yes
Country-input sector FE	no	no	no	yes
R-squared	0.040	0.040	0.038	0.060
Observations	6,589,556	6,589,556	6,589,556	6,589,556
Firms	66,429	66,429	66,429	66,429

Notes: The dependent variable is *Integration*$_{fijc}$, a dummy variable equal to 1 if firm f located in country c with primary output j integrates input i. The variable *CV Productivity*$_{ic}$ is the coefficient of variation of labor productivity of the suppliers in input industry i located in country c, while *Mean Productivity*$_{ic}$ is the mean of input suppliers' productivity. *Old*$_f$ is a dummy variable equal to 1 is the age of the firm exceeds the mean value in the sample. *Employment*$_f$ measures total firm employment, and *MNC*$_f$ is a dummy variable equal to 1 if the firm has subsidiaries in more than one country.

ADDITIONAL ROBUSTNESS CHECKS:

To be added.

Appendix

Table A-1: Descriptive statistics for firms in matched sample

	Mean	Median	Min	Max	S.D	N. firms
Decentralization$_f$	0,13	0,07			0,99	3444,00
Vertical Integration$_f$	0,10	0,08			0,08	3823,00
Management score$_f$	3,07	3,11			0,66	3444,00
Employment$_f$	673,02	300,00			1069,40	3820,00
Age$_f$						
MNC$_f$						
% workers with college degree$_f$	15,39	10,00			16,63	3311,00

Appendix

Table A-2: Descriptive statistics for firms in WorldBase sample

	Mean	Median	Min	Max	s.d.	N. observations	N. firms
Integration$_{fijc}$	0,014	0	0	1	0,115313	6589556	66429
Employment$_f$	281,93	45	20	1223240	5285,489	6589556	66429
MNC$_f$	0,062	0	0	1	0,24	6589556	66429
Age$_f$	34,20	26	0	405	29,23	6589556	66429
Old$_f$	0,062	0	0	1	0,24	6589556	66429
Mean productivity$_{ic}$	443685,6	335098,4	7234,11	2,92E+06	7,23E+03	6589556	66429
CV productivity$_{ic}$	3,612	2,203	0	149,832	5,680	6589556	66429

Table A-2: Option value of vertical integration (only manufacturing inputs)

	(1)	(2)	(3)	(4)	(5)	(6)
CV Productivity$_{ic}$	**0.00082*****	**0.00049*****	**0.00043*****	**0.00078*****	**0.00044*****	**0.00039*****
	(0.00023)	(0.00013)	(0.00012)	(0.00021)	(0.00012)	(0.00011)
Mean Productivity$_{ic}$	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)
log(Employment$_f$)	0.00568***	0.00558***		0.00663***	0.00661***	
	(0.00048)	(0.00048)		(0.00063)	(0.00063)	
log(1+ Age$_f$)	0.00121***	0.00159***		0.00145**	0.00195***	
	(0.00047)	(0.00038)		(0.00061)	(0.00048)	
MNC$_f$	0.00533***	0.00293**		0.00514***	0.00275	
	(0.00149)	(0.00148)		(0.00187)	(0.00186)	
Input sector FE	yes	yes	yes	yes	yes	yes
Country FE	no	YES	no	no	yes	no
Firm FE	no	no	yes	no	no	yes
R-squared	0.066	0.069	0.071	0.069	0.073	0.070
N	1188159	1188159	1187972	870073	870073	868621
Firms	66429	66429	66429	66314	66314	66314

Notes: The dependent variable is *Integration*$_{fijc}$, a dummy variable equal to 1 if firm f located in country c with primary output j integrates input i. The set of inputs is restricted to manufacturing (SIC code between 2000 and 3999). Columns (1)-(3) include all input industries i, while columns (4)-(6) includes only industries in which there are less than 50 suppliers to construct the variables *CV Productivity*$_{ic}$ and *Mean Productivity*$_{ic}$. The variable *CV Productivity*$_{ic}$ is the coefficient of variation of labor productivity of the suppliers in input industry i located in country c, while *Mean Productivity*$_{ic}$ is the mean of input suppliers' productivity. *Employment*$_f$ measures total firm employment, *Age*$_f$ is the number of years since the firm's establishment, and *MNC*$_f$ is a dummy variable equal to 1 if the firm has subsidiaries in more than one country.

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