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A PRICE THEORY OF VERTICAL AND LATERAL INTEGRATION UNDER PRODUCTIVITY HETEROGENEITY*

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We analyze the interplay between product market prices and firm boundary decisions. Enterprises are heterogeneous with respect to productivity and they choose between two ownership structures—while centralized ownership (integration) performs well in coordinating managerial actions, dispersed ownership (non-integration) is conducive to poor coordination. Ownership structure is monotone, i.e., high-productivity enterprises integrate while the low-productivity ones stay separate. Price can be positively or negatively associated with integration, depending on how price changes affect the distribution of surplus within an enterprise. A negative association may result in a backward-bending industry supply. Our model delivers novel empirical and policy implications.

I. INTRODUCTION

There is a plethora of evidence on heterogeneity of firm productivity within an industry, which is also associated with organizational variation at the firm level (e.g., Gibbons [2010]; Syverson [2011]) and endogenous sorting among firms (e.g., Hortaçsu and Syverson [2007]; Atalay, Hortaçsu and Syverson [2014]; Braguinsky, Ohyama, Okazaki and Syverson [2015]). In this paper, we analyze the interplay between product market competition and firm boundary decisions (choice of ownership structure) under productivity heterogeneity. We intend to shed light on the following questions pertaining to the Organizational Industrial Organization (OIO) literature which lies at the

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intersection of organizational and industrial economics: (i) what determines that diverse organizational modes such as integration and non-integration coexist in the same market?, (ii) what is the effect of product market competition on the likelihood of integration? and (iii) is the industry supply curve always upward-sloping, when we incorporate the possible reorganization of firms a price change induces?

The building block for the analysis is the model by Legros and Newman [2013]. Following their paper, we posit a model in which output is produced by combining two complementary assets, where each asset is run by a (cash constrained) manager. In the airline industry, for example, regional airlines operate as 'subcontractors' for major U.S. network carriers on short and medium-haul routes, often connecting smaller cities to the major carrier hubs, (see Forbes and Lederman [2009, 2010]). The output in this example is the service to the travelers who use two complementary flight segments, one served by a regional carrier and the other, by a major. In general, majors own some regional flights (integration), and outsource some services to independent firms (non-integration). As another example, consider the healthcare industry where as of 2015 approximately 20% of all Medicare fee-for-service hospital admissions ended in skilled nursing facility (SNF) stays (see Zhu, Patel, Shea, Neuman and Werner [2018]). In this example, hospitals and SNF's are the two complementary units that should coordinate to guarantee the best health outcome for each patient. Traditionally, hospitals and SNF's received separate payments for the care they provide. To reduce spending and improve quality of care, Medicare recently introduced bundled payment programs that link payments for multiple services related to a single episode of care. We can also interpret the level of output in the above examples as 'quality of services.'

In our model, the two units can integrate or stay separate and use revenue sharing contracts to govern their relationship. In order to focus on possible inefficiencies that emerge due to firm boundary decisions, we abstract from any other form of inefficiency that can arise from imperfections in the product market. In the decision of the two units about whether to integrate or not, they face a trade-off between coordination benefits and private costs. Under integration, better coordination of non-contractible managerial efforts boosts enterprise revenue, but at the expense of higher private costs for the managers, whereas the opposite is true when they remain separate. Air-carriers, for instance, under integration, can adopt common practices that reduce delays and other costs, but at the expense of a change in the managers' daily routine these common practices will introduce.[1] In response to the

[1] As discussed in Hart and Hölmstrom [2010], two firms may want to adopt a common standard, as in Cisco's acquisition of Stratacom. The benefits for the organization from a common standard can be enormous but the private costs within the firms may increase because of the change the new standard introduces. Moreover, there is no agreement between the firms about which 'approach' should be adopted. However, agreeing on a common approach (coordination) boosts firm revenue.

bundled payment initiative by Medicare, coordination and communication between hospitals and SNF's have improved either by integration or by formal contractual agreements (e.g., Zhu *et al*. [2018]).

Neither organization achieves full efficiency. Which one dominates the other depends crucially on the market price and how the total surplus in the relationship is distributed between the two units. A higher market price favors integration because it increases the value of output, and hence, the benefits from coordination, while a more balanced distribution of surplus favors non-integration because it adequately incentivizes the two managers to coordinate their efforts even when the two units are separate (as is standard in models of moral hazard in teams).

We extend Legros and Newman [2013] by introducing productivity heterogeneity among the enterprises. One firm from one side of the market, say side A, matches (forms a relationship) with a firm from the other side (one-to-one matching), say side B, to create an enterprise. These two firms also decide whether to remain separate as production units or to integrate, facing the trade-off between coordination benefits and private costs we discussed above. In our model, there is one-sided heterogeneity, i.e., one side of the market (the B firms) exhibits productivity heterogeneity, while all units on side A have identical productivity. Higher productivity units are more desirable, so there is competition among all homogeneous units for the high-productivity ones on the heterogeneous side. Differences in productivity of the B units imply differences in the enterprise productivity, and competition for the higher-productivity units endogenizes the distribution of surplus among the two units that comprise an enterprise. We show that, under fairly general conditions, the choice of ownership structure is monotonic—high-productivity enterprises integrate while low-productivity enterprises stay separate. The endogenous allocation of surplus in each enterprise means that such allocation is more biased in favor of the B units as one goes up the productivity ladder. As unbalanced shares in non-integrated enterprises are less conducive to coordination, high-productivity enterprises choose to integrate. Heterogeneity among enterprises thus induces robust coexistence of diverse ownership structures under the same market fundamentals.

The equilibrium outcome yields interesting predictions with respect to the effect of the competitiveness of the product market, as measured by the market price, on the incentives to integrate. A higher market price, as we discussed above, is a force in favor of integration, but at the same time it may lead to a more balanced utility allocation among the units, which is a force in favor of non-integration. One of our main results is that there may be a negative association between product market price and integration, which takes exception to the popular view that increased competition (lower price) necessarily leads to less integration. Under non-integration, utility is imperfectly transferred between the two units via revenue sharing contracts. This suggests that how much additional utility each side can receive when price, and hence surplus increase, depends on the position of the enterprise on its Pareto frontier which in turn depends, among other things, on the units' productivities and outside options. If a higher price leads to a more balanced sharing of surplus in the enterprise that is indifferent between integration and non-integration at the initial price, then this enterprise switches to non-integration. As a result, the fraction of non-integrated enterprises increases with price. By contrast, if a higher price causes more uneven distribution of surplus in the initially indifferent enterprise, then higher price induces more integration.

Holding the organizational structures in the market fixed, a higher market price implies higher aggregate output, because coordination under non-integration improves, and the aggregate output in the integrated enterprises is at its highest potential. On the other hand, if a higher price implies less integration, then this introduces a countervailing force on aggregate output because non-integrated firms produce in lesser quantity (or lower quality of services) than the integrated ones. If this force is stronger, then industry output may decrease with price. Thus, our second main result is that the organizationally augmented supply curve (OAS), which describes the price-quantity relationship taking the equilibrium organizational choices into account, can have downward-sloping segments due to the organizational restructuring a price change triggers.

Our results are significant because they help to show why 'opening the black box' of the firm may have dramatic implications for understanding industry behavior and performance, even to the point of challenging some of the most unquestioned ideas in industrial economics, such as upward-sloping supply curves. We offer a couple of novel testable implications. First, the ambiguity regarding the effect of an increase in the product market price on the decision to integrate suggests a non-monotonic association between competition and integration. Second, a downward-sloping industry supply curve implies that an inward shift of the product demand leads to lower price, higher output and more integration. Recent empirical studies found similar results (e.g., Hortaçsu and Syverson [2007]). However, our mechanism is different in the sense that we analyze the effect of price changes on integration, whereas this strand of empirical literature examines the effect of [vertical] integration on the product market price.

I(i). *Related Literature and Our Contribution*

The literature on OIO, which is concerned with how market structure affects firm boundaries decisions, is still in its early stages of development.[2] Our

[2] See Legros and Newman [2014] for an excellent survey. They argue: 'Nascent efforts at developing an OIO already suggest that market conditions or industrial structure matter for organization design. At the same time, organizational design will affect the productivity of firms, hence eventually the total industry output, the quality of products and information about this quality for consumers. Organizational design matters for consumers, hence for IO.'

paper adds to recent contributions to this literature. As we have mentioned earlier, for any given enterprise the decision to integrate depends on how the enterprise surplus is divided among the units. When shares are unbalanced, non-integration performs poorly in coordinating managerial actions because incentives cannot be easily aligned, and hence, integration is the preferred choice. However, this basic trade-off is not new. It has been explored in Legros and Newman [2013] and other prior works (e.g., Grossman and Helpman [2002]). Legros and Newman [2013] derive two main results: (i) despite a continuum of firms being homogeneous, the two organizational modes may co-exist in the market, and (ii) higher product market price makes integration more likely, and hence, the organizationally augmented industry supply curve is upward-sloping.

Coordination motives as the main driver of vertical and lateral integration has earlier been analyzed by Hart and Hölmstrom [2010], although there is no scope for an *ex ante* revenue sharing contract as *ex post* bargaining is efficient. The role of surplus sharing in determining the choice between vertical integration and outsourcing has been analyzed in Grossman and Helpman [2002]. However, their mechanism is different in the sense that large governance costs in the vertically integrated firms are balanced against costs arising from a holdup problem (as in Grossman and Hart [1986]) and search for suitable partners under outsourcing. In the equilibrium of the market with identical participants, either all firms vertically integrate or there is pervasive outsourcing. Extreme revenue share makes an equilibrium with integration more likely to occur because it generates excess demand or excess supply for intermediate inputs. Gibbons, Holden and Powell [2012] obtain generic heterogeneity of ownership by analyzing a rational-expectations equilibrium of price formation and endogenously chosen governance structures. They show that the informativeness of the price mechanism can induce *ex ante* homogeneous firms to choose heterogeneous governance structures.

We differ from the aforementioned works in the following aspects. In Legros and Newman [2013], all units are homogeneous, the revenue shares are endogenously determined, but the outside option of the firms on one side of the market is exogenously fixed. In Grossman and Helpman [2002], on the other hand, the share of intermediate input suppliers is exogenously given, which reflects the degree of input market competition, and it does not interact with the degree of product market competition. As we allow units to be *ex ante* heterogeneous, endogenous matching leads to an endogenous distribution of surplus. Even when Legros and Newman [2013] allow for *ex ante* heterogeneity in firm productivities, because the matching is exogenous, all units who receive offers consume their fixed reservation payoff. In light of our framework, the same utility allocation or surplus sharing cannot be part of a stable equilibrium as more productive units must receive higher utility. The endogenous distribution of surplus in our model has further implications for the association between product market price and integration. Due to endogenous matching, the surplus division in the infra-marginal firms determines how balanced the surplus sharing is in the marginal firm, which in turn determines the choice of ownership structure of the marginal firm following a price increase. Higher surplus can generate a more even allocation of utilities in the marginal firm, which favors non-integration. Therefore in our model, a rise in price may lead to less integration, and consequently, the industry supply curve may be backward bending.[3]

To summarize, our contribution is that we provide a particular mechanism, which relies on productivity heterogeneity, to illustrate how the effect of surplus sharing on firm boundary decisions manifests itself in the market.[4] In doing so, we offer a more complete picture of the interaction of market price with integration decisions and output, given that productivity heterogeneity is ubiquitous in markets.

Coexistence of various modes of organization under productivity heterogeneity and endogenous matching resembles models of occupational and contract choices under heterogeneity. Chakraborty and Citanna [2005] examine an occupational choice model with wealth heterogeneity, two-sided moral hazard and matching. As in our model, the division of the gains from a match is determined by competitive forces. They show that matches are typically wealth heterogeneous with richer individuals choosing occupations for which incentives are more important. In a model of managerial incentives under endogenous matching, Alonso-Paulí and Pérez-Castrillo [2012] analyze the choice between incentive and codes of best practice (CBP) contracts. The presence of two different contracting modes gives rise to a non-concave bargaining frontier for each shareholder-manager pair, as it is the case in our model. Macho-Stadler, Pérez-Castrillo and Porteiro [2014] show the robust co-existence of two contracting modes—namely, short and long-term contracts in a labor market where heterogeneous firms are endogenously matched with heterogeneous workers.

[3] Legros and Newman [2013], pp.746-747, discuss how a technological shock that impacts only a fraction of the firms in the market affects the organization of all firms. It turns out that the shock leads to less integration by the firms unaffected by the shock, and hence, less output. This is an example of an organizational external effect: the organizational change comes from outside the firm, transmitted by the market. The reorganization in our model, caused by a price change, operates through different channels: the distributional as well as the price channels, but there are similarities. Most notably, the organizational external effect is also a force in our model and propagates through the endogenously determined outside options.

[4] Productivity heterogeneity has also become increasingly important in the context of international trade, as there are easily available datasets with detailed information about the matching between exporters and importers (e.g., Bernard, Moxnes and Ulltveit-Moe [2018]; Dragusanu [2014]; Sugita, Teshima and Seira [2020]).

II. THE MODEL

II(i). *Technology and Matching*

Consider a two-sided market where on each side there is a continuum of firms or (supplier) units. For tractability, we assume that firms on one side, call it the A side, are homogeneous while firms on the other side, the B firms, are heterogeneous with respect to their productivities. In particular $A = \{a\}$ with $a > 0$, and $B = (0, b_{max}]$.[5] We further assume that the B firms are on the long side of the market, i.e., the measure of side B is higher than that of the other side.[6]

Production of a homogeneous consumer good requires one A unit and one B unit who are matched one-to-one to form an 'enterprise'. Formally, a matching is a one-to-one mapping α: $B \to A$ which assigns to each $b \in B$ a firm in A. Given that the A side is homogeneous, the matching function is a constant function, i.e., $\alpha(b) = a$. The units that form an enterprise may have a lateral or a vertical relation. The stochastic output of a typical enterprise (a, b) is given by:

$$\tilde{y}(a, b) = \begin{cases} az(b) \text{ with probability } \pi(e_A, e_B) \equiv 1 - (e_B - e_A)^2, \\ 0 \qquad \text{otherwise.} \end{cases}$$

Because the A units are homogeneous, their type a represents the 'total factor productivity' of the enterprise output. We assume that $z(b)$ is twice continuously differentiable, strictly increasing and concave on B. Each unit must make a non-contractible production decision: $e_A \in [0, 1]$ by an A firm and $e_B \in [0, 1]$ by a B firm. These decisions can be made by the manager of the assets or by someone else. If the two managers coordinate their decisions and set $e_A = e_B$, then inefficiencies disappear and the enterprise reaches its full potential $az(b)$ with probability 1. The manager of each firm is risk neutral and incurs a private cost for the managerial action. The private cost of an A unit is e_A^2, and that of a B unit is $(1 - e_B)^2$. Clearly, there is a disagreement about the direction of the decisions, what is easy for one is hard for the other. Also, managers with zero cash endowments are protected by limited liability, i.e., their state-contingent incomes must always be non-negative. The importance of this assumption is that the division of surplus between the managers will affect the organizational choice.

[5] Bloom and van Reenen [2007], using a survey from medium-sized manufacturing firms from four countries, document that management practices are heterogeneous and affect firm performance. Gibbons [2010] offers a more detailed account of various empirical studies that document persistent performance differences (PPD's). In the computer industry, computer systems manufacturers rely on networks of independent component suppliers. These suppliers are of various 'qualities' and produce components that are used as inputs in the production of the final product (see Fallick, Fleischman and Rebitzer [2006]).

[6] Later, in Section V(i), we discuss the implications if we relax this assumption.

II(ii). *Ownership Structures and Contracts*

The ownership structure can be contractually determined. We assume two different options, each of which implies a different allocation of decision rights. First, the production units can remain as separate firms (the *non-integration* regime, denoted by N). In this case, managers have full control over their decisions. Second, the two units can integrate, a regime denoted by I, into a single firm by selling their assets to a third party, called the headquarter (HQ), which gives HQ full control over managerial decisions, e_A and e_B, assuming that the third party possesses enough cash to finance the acquisition.[7] The headquarter is motivated entirely by revenue and incurs no costs from the managerial decisions. These costs are still borne by the managers. As argued by Hart and Hölmstrom [2010], integration results in an organization where less weight is placed on private costs than under non-integration. This, however, is offset by the fact that under integration total revenue, rather than individual unit profits, is maximized.

The revenue of each enterprise is publicly verifiable, and hence, *ex ante* contractible. We assume that each A firm has all the bargaining power in an arbitrary enterprise (a, b) and makes take-it-or-leave-it contract offer to the B firm.[8] For each enterprise, a contract $(s, d) \in [0, 1] \times \{N, I\}$ specifies a revenue share s for the B unit and an ownership structure d. As we assume limited liability, the units get nothing in the case of failure.

When the two units integrate, HQ buys the assets of the A and B units at predetermined prices in exchange of a share contract $\mathbf{s} = (s_A, s_B, s_{HQ}) \in \mathbb{R}^3_+$ with $s_A + s_B + s_{HQ} = 1$. HQ's are supplied perfectly elastically with an opportunity cost normalized to zero.

II(iii). *The Product Market*

The product market is perfectly competitive where consumers and producers take the product price P as given. Identical consumers maximize a smooth quasi-linear utility which gives rise to a downward-sloping demand curve

[7] The two units supply complementary inputs to produce a single homogenous good. If we think of enterprises as vertical relationships, one unit, say, A may be named the 'upstream' firm, and the other, the 'downstream' firm. In our model, lateral and vertical relationships are somewhat equivalent because the sole motive for integration is to improve coordination among the units which is achieved by conferring the decision making rights on a third party. We do not consider vertical integration in a more traditional sense where the rights to make decisions belong to the integrated entity, and in which there are the usual efficiency gains such as ameliorating the problem of double marginalization.

[8] In a model with a continuum of types, a particular bargaining protocol is irrelevant, and hence, assuming a take-it-or-leave-it bargaining protocol is innocuous. This is because the factor owners do not earn rents over their next best opportunity within the market, as types are arbitrarily close to each other. However, in a model with discrete types there would be a match-specific rent left for bargaining.

$D(P)$. Enterprises correctly anticipate price P when they sign contracts and make their production decisions.

II(iv). *Timing of Events*

The economy lasts for two dates, $t = 1, 2$. At date 1, one A firm and one B firm match one-to-one to form an enterprise, and each A unit makes a take-it-or-leave-it contract offer (s, d) to each B unit. At date 2, the manager of each unit chooses e_A and e_B. We solve the model by backward induction.

II(v). *Equilibrium*

An equilibrium of the input market consists of a set of enterprises formed through feasible contracts, i.e., ownership structures and corresponding revenue shares for each enterprise and a market-clearing price. Recall that there are two possible ownership structures for each enterprise—non-integration (N) and integration (I). In general, choice of ownership structures depends on the revenue share that accrues to each member of an enterprise, the output of each enterprise and the market price. An allocation for the market $\langle \alpha, v, u \rangle$ specifies a one-to-one matching rule $\alpha: B \rightarrow A$, and payoff functions $v: A \rightarrow \mathbb{R}_+$ and $u: B \rightarrow \mathbb{R}_+$ for the A and B firms, respectively.

Definition 1. (Equilibrium). An allocation $\langle \alpha, \mathrm{v}, \mathrm{u} \rangle$ and a product-market price P constitute an equilibrium allocation of the economy if they satisfy the following conditions:

(a) *Feasibility:* The revenue shares and the corresponding payoffs to the firms in each equilibrium enterprise are feasible given the output of the enterprise and the equilibrium price P;

(b) *Optimization:* Each A firm chooses optimally a B firm to form an enterprise (a, b), i.e., given u for each $b \in B$, each A firm solves

$$v = \max_b \phi(a, b, u, P).$$

The function $\phi(a, b, u, P)$ is the bargaining or Pareto frontier of the enterprise (a, b), which is the maximum payoff that can be achieved by an A unit given that the B unit of type b consumes u at each given market price P.

(c) *Product market clearing:* The aggregate (expected) supply in the industry $Q(P)$ is equal to the demand $D(P)$.

III. OPTIMAL OWNERSHIP STRUCTURE FOR AN ARBITRARY ENTERPRISE

We analyze the optimal contract for an arbitrary enterprise. We first study each ownership structure separately. Note that the heterogeneity among the enterprises is entirely explained by the heterogeneity of the B firms. Write $z \equiv az(b)$ which is the output or productivity of a generic enterprise (a, b). Because $z'(b) > 0$, we can write $b = b(z)$ where $b(\cdot)$ is the inverse function. From now on, we denote a typical enterprise by its productivity z instead of (a, b). To save on notation, we suppress the dependence of the payoffs on the product market price P until Section V where we analyze the effect of changes in P on the equilibrium allocations. Let $R \equiv Pz$ be the revenue of an enterprise z in the event of success.

III(i). *Non-Integration*

Under this organizational mode, the shares affect both the size and the distribution of surplus between the two units (imperfectly transferable utility). An optimal contract for a non-integrated enterprise solves the following maximization problem:

$$\max_{s} V_A \equiv \pi(e_A, e_B)(1-s)R - e_A^2, \tag{1}$$

$$\text{subject to} \quad U_B \equiv \pi(e_A, e_B)sR - \left(1 - e_B\right)^2 = u, \tag{2}$$

$$e_A = \operatorname*{argmax}_{e} \left\{\pi(e, e_B)(1-s)R - e^2\right\}, \tag{3}$$

$$e_B = \operatorname*{argmax}_{e} \left\{\pi(e_A, e)sR - (1-e)^2\right\}, \tag{4}$$

where u is the outside option of the B unit. We assume that $u \geq u_0$, where $u_0 > 0$ is the reservation utility of the B firms, i.e., the utility any B firm would obtain if it stays unmatched. The reservation utility of the A firms is $v_0 > 0$. Constraint (2) is the *participation constraint* of the B firm, whereas constraints (3) and (4) are the *incentive compatibility constraints* of the A firm and the B firm, respectively. When the firms in an arbitrary enterprise z stay separate, at a given product market price P, the maximum payoff that accrues to the A unit given that the B unit consumes u is given by:

$$\phi^N(z, u) = u - R^2 + \frac{R}{1+R}\sqrt{R^2(2+R)^2 - 4(1+R)^2 u} \quad \text{for } 0 \leq u \leq \frac{R^2}{1+R}.$$

The function $\phi^N(z, u)$ is the bargaining frontier under non-integration at a given market price P. The participation constraint of the B unit determines the optimal revenue share $s = s(z, u)$ of the B firm in each enterprise z. The bargaining frontier is strictly increasing in P and z, and hence in R, and strictly decreasing in u. Note that u must lie between 0, which corresponds to $s = 0$, and $R^2/(1 + R)$, the level corresponding to $s = 1$. The frontier is symmetric with respect to the 45° line, on which $\phi^N(z, u) = u$ and $s = 1/2$. This implies that total surplus is maximized when the shares across the two non-integrated units are equal. Equal or, more broadly, 'balanced' shares provide strong incentives for the managers to coordinate better their decisions, i.e., e_A and e_B move closer to each other. Finally, higher revenue R, holding the shares fixed, also induces better coordination. At a given product market price P, any non-integrated enterprise z produces an expected output which is given by:

$$q^N(z, P) = \underbrace{\pi(e_A, e_B)}_{\frac{R(2+R)}{(1+R)^2}} \cdot z = z\left(1 - \frac{1}{(1 + Pz)^2}\right).$$

Note that $q^N(z, P)$ is strictly lower than z, i.e., a non-integrated enterprise does not reach its full potential.

III(ii). *Integration*

When the units integrate, the enterprise is acquired by HQ which is conferred with the decision making right. Motivated entirely by incomes, HQ will choose e_A and e_B to maximize the expected revenue $\pi(e_A, e_B)R$ as long as $s_{HQ} > 0$. This induces $e_A = e_B$, and hence, $\pi(e_A, e_B) = 1$ for all integrated enterprises. Each HQ breaks even as they do not posses market power. The private costs of managerial actions are still borne by the individual units. The aggregate managerial cost, $e_A^2 + (1 - e_B)^2$, is minimized when $e_A = e_B = 1/2$. Thus, the bargaining frontier under integration is given by:

$$\phi^I(z, u) = R - \frac{1}{2} - u \quad \text{for } 0 \leq u \leq R - \frac{1}{2}.$$

The above function is linear in u, i.e., surplus is fully transferable between the two managers because neither the action taken by HQ nor the costs borne by the managers depends on the revenue shares. The function $\phi^I(z, u)$ is strictly increasing in P and z, strictly decreasing in u (with slope -1) and symmetric with respect to the 45° line. The expected output produced by an arbitrary integrated enterprise z is given by:

$$q^I(z, P) = \underbrace{\pi(e_A, e_B)}_{1} \cdot z = z.$$

Although surplus is fully transferable between the A and B firms, this form of organization is in general not efficient as HQ, having a stake in the enterprise's revenue, places too little weight on private managerial costs while maximizing expected revenue.[9]

III(iii). *Choice of Ownership Structure*

We now analyze the optimal choice of ownership structure by a given enterprise. At any given product market price P and utility u accruing to the B firm, an arbitrary enterprise z would choose N over I if and only if $\phi^N(z, u) > \phi^I(z, u)$. In an enterprise z, the optimal choice of ownership structure depends on the revenue of the enterprise, R as well as the way the enterprise revenue or equivalently, the aggregate surplus is shared between the two units. Low revenue, i.e., $R < 1$ implies that an enterprise places more emphasis on private costs relative to the benefits accruing from coordination, and hence, the aggregate surplus from non-integration is strictly higher than that under integration, i.e., $\phi^N(z, u) > \phi^I(z, u)$ for all levels of u. Thus, the enterprise chooses non-integration over integration irrespective of the revenue share. By contrast, for the high-revenue (or high-productivity) enterprises with $R \geq 1$, there is no clear dominance of one mode of organization over the other, and hence, the choice of organizational mode depends on how the surplus of the enterprise is distributed between the two units, i.e., on the levels of u. This case is depicted in Figure 1 where the strictly concave frontier is the one associated with N, i.e., $\phi^N(z, u)$, and the linear frontier is $\phi^I(z, u)$, the frontier associated with I. Because both frontiers are symmetric with respect to the 45° line, they intersect exactly twice at utility allocations (u_L, v_H) and (u_H, v_L) which are given by:

$$u_L(z) = v_L(z) = \frac{(R-1)(1+2R)}{4(1+R)} \quad \text{and} \quad u_H(z) = v_H(z) = \frac{2R^2+3R-1}{4(1+R)}.$$

The (combined) bargaining frontier of an enterprise z is given by:

$$\phi(z, u) = \max\left\{\phi^I(z, u), \phi^N(z, u)\right\}.$$

It is easy to show that $\phi(z, u)$ is strictly increasing in z, and strictly decreasing in u. When $R \geq 1$, for intermediate values of u, i.e., $u_L(z) \leq u \leq u_H(z)$, an enterprise prefers to stay separate because the corresponding revenue shares s and $1-s$ are more balanced, and so coordination among the two units can more easily be achieved without being integrated. On the other hand, for the

[9] The first-best surplus, $\frac{2R^2}{1+2R}$, is strictly higher than $R - \frac{1}{2}$, the surplus accrued to an integrated firm as well as $\left(\frac{3}{2}+R\right)\left(\frac{R}{1+R}\right)$, the maximum surplus in a non-integrated firm, which corresponds to $s = \frac{1}{2}$. The diminished output under non-integration reflects the distortionary effect of incentive contracting.

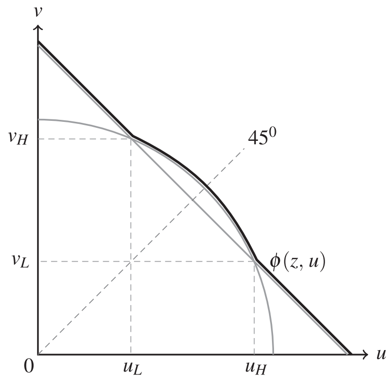

Figure 1

Notes: For $R \geq 1$, the bargaining frontier $\phi(z, u)$ of a given enterprise z is the upper envelope of $\phi^N(z, u)$, the concave frontier and $\phi^I(z, u)$, the linear frontier. Non-integration is preferred over integration for intermediate values of u, i.e., $u_L \leq u \leq u_H$. By contrast, integration is the preferred choice for low or high values of u, i.e., $u < u_L$ or $u > u_H$.

extreme values of u, either high or low, integration is preferred because the shares are tilted in favor of one of the two units, and the incentives for revenue maximization are weak.[10]

IV. EQUILIBRIUM OWNERSHIP STRUCTURE

The equilibrium allocation. It is straightforward to show that in any equilibrium allocation:

1. All A firms are matched, while some B firms stay unmatched because they are on the long side of the supplier market. Let b_0 denote the lowest-productivity B firm that is matched in equilibrium. Then, any B unit with productivity less than or equal to b_0 is unmatched.[11]
2. Because the B firms are on the long side of the market, the lowest-productivity B that is matched in equilibrium, i.e., b_0, must consume the reservation utility u_0 at any product market price P. On the other hand, given that A firms are homogeneous, they all must receive the same payoff because if any two matched A firms obtain different payoffs, then the A unit consuming lower payoff can undercut the one with the higher payoff. The payoff of any A unit is thus completely determined by the utility allocation in the lowest-productivity enterprise $z_0 \equiv az(b_0)$, i.e.,

$$v = \phi(z_0, u_0) \quad \text{for all } A \text{ firms.}$$

[10] Notice that, for $R < 1$, $u_L(z), v_L(z) < 0$ and $u_H(z)$, $v_H(z) > R^2/(1+R)$.

[11] There may be many B firms with the lowest productivity level b_0 such that total measure of the B firms exceeds that of the A firms. In this case, some randomly chosen B units with productivity b_0 will stay unmatched.

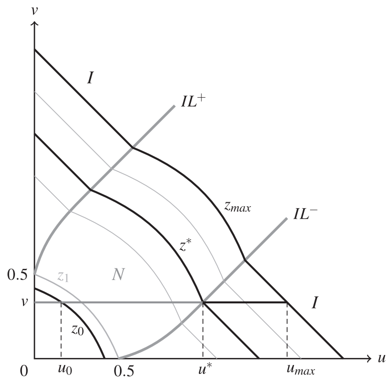

Figure 2
The Equilibrium Utility Allocations and the Monotone Ownership Structure.

Notes: Low-productivity ($z < z^*$) enterprises stay separate, and high-productivity enterprises integrate.

3. Because all A firms consume the same utility, any $b > b_0$ obtains

$$u = \begin{cases} v - R^2 + \dfrac{R}{1+R}\sqrt{R^2(2+R)^2 - 4(1+R)^2 v} & \text{if } v \in [v_L(z),\ v_H(z)], \\ R - \dfrac{1}{2} - v & \text{otherwise.} \end{cases}$$

Note that u is strictly increasing in b, and hence, z because $z'(b) > 0$.[12]

Equilibrium choice of organization. In what follows we characterize the ownership structures that emerge in the equilibrium of the input market at any given product market price P. The type of equilibrium of our interest is the monotone equilibrium in which low-productivity enterprises choose to stay separate, whereas high-productivity enterprises integrate.

In Figure 2, each bargaining frontier represents an enterprise with a given productivity—the higher the enterprise productivity, the higher is the frontier. The frontier labeled z_0 corresponds to the lowest-productivity enterprise, whereas the one labeled z_{max} is associated with the highest-productivity enterprise. The bargaining frontiers of all other enterprises lie between these two (imagine a continuum of frontiers such as the gray ones). One frontier of particular interest is the one labeled z_1 at which $R_1 \equiv Pz_1 = 1$. We assume that enterprise z_0 generates low revenue, i.e., $R_0 \equiv Pz_0 \leq 1$ so that it stays

[12] The equilibrium utility of the B firms is derived by taking the inverse of the bargaining frontier with respect to u, and using the fact that both the non-linear and linear frontiers are symmetric with respect to the 45^0-line. Also note that $u \in [u_L(z), u_H(z)]$ is equivalent to $v \in [v_L(z), v_H(z)]$.

separate at all prices. Therefore, the frontier of z_0 (which is non-linear and corresponds only to non-integration) is lower than that of z_1. We also assume that for the highest-productivity enterprise, non-integration is never a strictly dominant choice, i.e., $Pz_{max} \geq 1$. Consider now the enterprises with productivity greater than z_1, i.e., $Pz > 1$. Recall that each of these enterprises has two indifferent points: (u_L, v_H) and (u_H, v_L). Joining these points we obtain the *indifference loci* (the thick gray curves) which are given by $|v-u| = R/(1+R)$. The locus labeled IL^- represents the utility allocations $(u_H(z), v_L(z))$ for each z, and the one labeled IL^+ is the combination of points $(u_L(z), v_H(z))$ for each z. The curves start at $R_1^2/(1+R_1) = 0.5$. At any given price, the indifference loci divide the utility space into disjoint regions in which the enterprises either choose N or I, and they are indifferent between the two organizational modes along IL^- and IL^+.

We assume the range of variation of the product market price to be $[P_0, P_{max}] \equiv [1/z_{max}, 1/z_0]$. At any P, the equilibrium choice of organization depends on the level of enterprise revenue as well as how the revenue is shared between the A and B firms in each enterprise. Because the lowest-productivity enterprise chooses non-integration at all prices, all A firms consume $v = \phi^N(z_0, u_0)$. The following proposition characterizes the equilibrium organizations.

Proposition 1. At any product market price $P \in [P_0, P_{max}]$, the equilibrium ownership structure is monotone, i.e., there is a unique $z^* \in (z_0, z_{max}]$ such that an enterprise z integrates if and only if $z > z^*$, where z^* solves

$$v_L(z) = \phi^N(z_0, u_0). \tag{5}$$

The proofs of the above proposition and some subsequent results are in Appendix A. Recall that the common level of utility that accrues to the A units is completely pinned down by the lowest-productivity enterprise, which is represented by the horizontal line labeled v in Figure 2. The lowest-productivity enterprise z_0 chooses N irrespective of the distribution of surplus between A and B. Given that the A firms in all enterprises obtain the same equilibrium payoff, as one moves up the productivity ladder of the B firms, the distribution of surplus becomes more and more unequal in favor of the B units which increases the likelihood of integration. Enterprise z^* is the unique indifferent enterprise because the horizontal line at v crosses the indifference locus at a unique utility allocation, $(u_H(z^*), v_L(z^*))$ with the B unit consuming $u^* = u_H(z^*)$. Any $z < z^*$ chooses to stay separate. In the highest-productivity enterprise z_{max} the share of surplus is very unbalanced in favor of the B firm (v crosses the bargaining frontier of z_{max} below IL^-), and hence, this enterprise including any $z \in (z^*, z_{max})$ choose to integrate.

Therefore, with heterogeneous enterprises, at each given product market price, both organizational modes coexist in the market with some enterprises choosing to integrate, some staying separate, and a unique type being indifferent between the two structures. Clearly, given our assumption that $Pz_0 \leq 1$, there cannot be any equilibrium on IL^+, i.e., z^* must lie on IL^-. It is worth noting that if z_{max} is not very high, then v may intersect its bargaining frontier between the two indifferent loci (in region N), i.e., $z_{max} \leq z^*$ implying that in equilibrium no enterprise chooses I. If we relax the assumption that $Pz_0 \leq 1$, then there are other types of equilibria which we analyze in Appendix B.

V. EFFECT OF PRICE CHANGES ON THE EQUILIBRIUM

In this section, we analyze the effects of an exogenous increase in the product market price on (a) the enterprises' decision to integrate, and (b) the aggregate industry output.

V(i). *Incidence of Integration*

We first examine how a change in the product market price P affects the fraction of integrated enterprises in the input market. From now on we write all the equilibrium variables and associated payoffs as functions of P as we intend to analyze the effect of changes in price. For example, we shall denote by $v_L(z, P)$ the utility of the A firms at which they are indifferent between N and I for a given P.

Our object of interest is the indifference locus IL^- because the unique indifferent enterprise z^* lies on it. In Figure 3, the curve labeled $v_L(z, P)$ is an equivalent representation of IL^- because for each z, there is a unique v_L that leaves the enterprise indifferent between N and I. Note that $Pz = 1$ is equivalent to $v_L(z, P) = 0$ which yields $z = z_1(P) = 1/P$. We do not draw $v_H(z, P)$ because the indifferent enterprise does not lie on IL^+. The unique indifferent enterprise at any given P thus solves $v_L(z, P) = \phi^N(z_0, u_0, P)$. In Figure 3, the equilibrium indifferent enterprise at price P is denoted by $z^*(P)$. Let $G(z)$ be the fraction of enterprises with productivity less than or equal to z, and let $g(z)$ be the corresponding density function with $g(z) > 0$ for all $z \in [z_0, z_{max}]$.[13] At any price P, the fraction of integrated enterprises or the probability of integration is thus given by $1 - G(z^*(P))$. Therefore, to see the impact of an increase in the product market price on the incidence of integration, it suffices to analyze how $z^*(P)$ changes following an increase in the product market price.

[13] The probability distribution of z is derived from the underlying distribution of b. Thus, $g(z) = f(b(z))b'(z)$ where $f(b)$ is the pdf of b, and $b(z) \equiv z^{-1}(z/a)$.

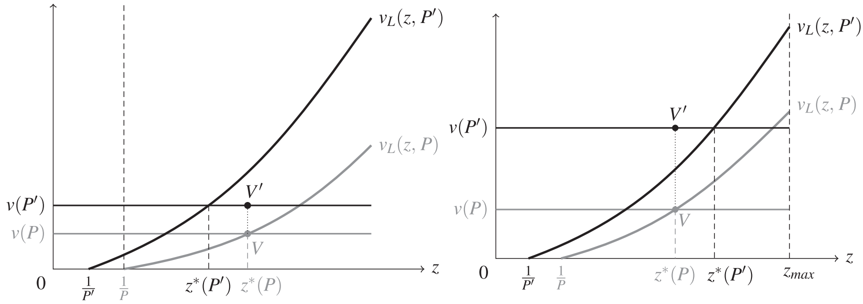

Figure 3

The Indifferent Enterprises at Two Distinct Market Prices P and P' with $P' > P$.

Notes: In the left panel, the shift in $v(P)$ due to price increase is smaller than that of $v_L(z, P)$ around $z^*(P)$, and hence, $z^*(P') < z^*(P)$, i.e, the fraction of integrated enterprises is higher at the higher price. In the right panel, the shift in $v(P)$ is larger, and hence, the probability of integration lower at the higher price.

Let P denote the initial price and P' the increased price. Because v_L is strictly increasing in P for each z, the curve $v_L(z, P)$ shifts up to $v_L(z, P')$ following an increase in the product market price. Moreover, the vertical distance between $v_L(z, P')$ and $v_L(z, P)$ increases with z.[14] On the other hand, because $\phi^N(z_0, u_0, P)$ is strictly increasing in P, the common level of utility of the A firms shifts up in parallel from $v(P)$ to $v(P')$. The [new] indifferent enterprise at the increased price P' is denoted by $z^*(P')$ at which $v(P')$ and $v_L(z, P')$ intersect each other.

In the left panel of Figure 3, around $z^*(P)$, the indifferent enterprise at the initial price P, the shift in $v(P)$ is smaller than that of $v_L(z, P)$, and hence, $z^*(P') < z^*(P)$. Consequently, the fraction of integrated enterprises increases following a price increase, i.e., $1 - G(z^*(P')) > 1 - G(z^*(P))$. Let point V represent the utility of the A unit in enterprise $z^*(P)$ at the initial price P. At the increased price P', its utility is at V' which is lower than $v_L(z^*(P), P')$. Thus, $z^*(P') < z^*(P)$ is equivalent to the fact that $z^*(P)$, the initially indifferent enterprise, chooses I at the increased price P' because the distribution of surplus at enterprise $z^*(P)$ becomes more unbalanced in favor of the B unit, i.e., $v(P') < v_L(z^*(P), P')$. In the right panel, the relationship is reversed. A larger shift in $v(P)$ relative to $v_L(z, P)$ around $z^*(P)$ implies that the distribution of surplus in enterprise $z^*(P)$ is more balanced at the new price P', and hence, the probability of integration decreases with P. In the following proposition, we state one of our main results.

[14] Given that $v_L(z, P) = \frac{(Pz-1)(1+2Pz)}{4(1+Pz)}$, we have $\frac{\partial v_L}{\partial P} = \frac{Pz^2(2+Pz)}{2(1+Pz)^2} > 0$ and $\frac{\partial^2 v_L}{\partial z \partial P} = \frac{Pz(P^2z^2+3Pz+4)}{2(1+Pz)^3} > 0$.

Proposition 2. The effect of an exogenous increase in the product market price on the fraction of integrated enterprises is in general ambiguous.

(a) A sufficient condition for positive association between the product market price and integration is

$$v(P') - v(P) \leq v_L(z_1(P), P') - v_L(z_1(P), P) \text{ for all } P, P' \in [P_0, P_{max}] \text{ and } P' > P. \tag{6}$$

(b) On the other hand, a sufficient condition for negative association between the product market price and integration is

$$v(P') - v(P) \geq v_L(z_{max}, P') - v_L(z_{max}, P) \text{ for all } P, P' \in [P_0, P_{max}] \text{ and } P' > P. \tag{7}$$

Condition (6), which is related to the left panel of Figure 3, asserts that the minimum increase in $v_L(z, P)$, which is the vertical distance between $v_L(z, P')$ and $v_L(z, P)$ at $z = z_1(P) = 1/P$, is larger than the shift in $v(P)$. An increase in the product market price implies an increase in the revenue of each enterprise. This increased revenue must be shared between the two units. Condition (6) guarantees that the share of surplus is very unbalanced in favor of the B firm in the initially indifferent enterprise $z^*(P)$, and hence, this enterprise strictly prefers I rather than being indifferent between integration and non-integration. Condition (7), on the other hand, implies that the maximum possible difference between $v_L(z, P')$ and $v_L(z, P)$, which occurs at $z = z_{max}$, cannot be larger than the increase in the utility of the A firms, which is the vertical distance between $v(P')$ and $v(P)$. Thus, at the increased price P', the revenue share is more balanced for the initially indifferent enterprise $z^*(P)$, and hence, this enterprise chooses non-integration.

Note that the two conditions (6) and (7) depend only on the exogenous parameters—namely, z_0, z_{max}, u_0 and P. We show that the parameter spaces over which the two sufficient conditions hold are non-empty (see Proof of Proposition 2 in Appendix A). If z_{max} is very high, then so is the difference $v_L(z_{max}, P') - v_L(z_{max}, P)$. In this case, condition (7) is less likely to hold. So, for condition (7) to hold it is necessary that z_{max} is not very high.[15]

Remark. If the A firms were on the long side of the market, then in any equilibrium allocation we would have $v = v_0$. In this case, the utility of the A units would have been independent of the market price, i.e., $v(P') - v(P) = 0$. Consequently, condition (6) would trivially hold. Thus, an

[15] The *Mathematica* codes for this and some subsequent results are available from the authors upon request.

increase in the product market price would have unambiguously implied an increase in integration. However, this result is true under the assumption that the lowest-productivity enterprise z_0 chooses N at any product market price. In Appendix B, we relax this assumption, and show that the equilibrium ownership structure can be non-monotonic, and there can be a negative relationship between price and integration even if v is insensitive to price changes [cf., Proposition 5].

We have also assumed the B firms to be on the long side of the market for tractability. A consequence of this is that the A firm at the lowest-productivity enterprise reaps the entire benefit of price increase, i.e., the shift in $v(P)$ is the maximum. Instead, we could have assumed that the measures of both sides were equal and the least productive enterprise distributed its surplus following some bargaining protocol so that the utility of the B firm in this enterprise is also an increasing function of P. The utility of the A firms would still be an increasing function of price and the result in Proposition 2 would be qualitatively similar.

V(ii). *Organizationally Augmented Industry Supply*

We now derive the industry supply curve (OAS) that describes the price-quantity relationship by taking the firm boundary decisions into account. The industry supply is the expected output aggregated across all the enterprises in the market equilibrium, which is given by:

$$Q(P) = \int_{z_0}^{z^*(P)} q^N(z,P)g(z)dz + \int_{z^*(P)}^{z_{max}} q^I(z,P)g(z)dz \ \text{ for } \ P \in [P_0, P_{max}],$$

The OAS is possibly non-monotonic. To see this, differentiate $Q(P)$ to get

$$Q'(P) = -\underbrace{g(z^*(P))[q^I(z^*(P),P) - q^N(z^*(P),P)]}_{(+)} \cdot \underbrace{\frac{dz^*(P)}{dP}}_{(-/+)} + \underbrace{\int_{z_0}^{z^*(P)} \frac{\partial q^N(z,P)}{\partial P} g(z)dz}_{(+)}. \tag{8}$$

A change in the product market price P affects $Q(P)$ via two channels—a rise in P (i) changes the fraction of integrated enterprises by changing the indifferent enterprise $z^*(P)$, which is captured by the first term of the above expression, and (ii) augments the output $q^N(z, P)$ of each non-integrated enterprise, but leaves the integrated output $q^I(z, P)$ unaltered—captured by the second term. Moreover, these two effects may point in opposite directions because the first term of the above expression may be positive or negative depending on the sign of $dz^*(P)/dP$. If there is a positive association between the product market price and integration, i.e., $dz^*(P)/dP < 0$ for all price levels, then $Q'(P) > 0$, and hence, the industry supply curve is upward-sloping. On the other hand, a negative association between the product market price and integration, i.e., $dz^*(P)/dP > 0$ is only a necessary (but not sufficient) condition for $Q'(P) < 0$, because the second term of the above expression is always positive due to $q^N(z, P)$ being strictly increasing in P.

Proposition 3. A positive association between the product market price and integration is a sufficient condition for the organizationally augmented industry supply $Q(P)$ to be upward-sloping. However, $Q(P)$ may have a downward-sloping segment. A necessary condition for the downward-sloping supply curve is a negative association between the product market price and integration, i.e., $dz^*(P)/dP > 0$.

It is not easy to write a simple sufficient condition under which the negative term in the expression of $Q'(P)$ would dominate the positive one whenever $dz^*/dP > 0$. Nevertheless, there are two ways in which the negative term can be large in magnitude. First, if $g(z^*(P))$ is sufficiently high, then whenever $dz^*/dP > 0$, a very large fraction of enterprises close to $z^*(P)$ would switch to non-integration under an increased market price, thereby inducing a concomitant drop in the aggregate industry output. Second, the impact of the negative term is significant if the difference between the integration and non-integration outputs is large enough around $z^*(P)$. Note that at any z,

$$q^I(z, P) - q^N(z, P) = \frac{z}{(1 + Pz)^2}.$$

So, the above difference is more likely to be large when the product market price is low, and hence, one would expect to have a downward-sloping OAS for low prices, and an upward-sloping supply curve for high prices. In the following example we show that the industry supply curve can be non-monotonic.

Example 1. (Non-monotonic OAS). We assume that the enterprise productivity z follows Beta distribution with shape parameters (5, 1) on the support $[z_0, z_{max}] = [0.5, 0.8]$. We take $u_0 = 0.25$. The range of variation of the product market price is [1.28, 2].[16] Figure 4 depicts a non-monotonic organizationally augmented supply curve. As expected, for low prices, the OAS is downward-sloping, whereas for high prices, it is upward sloping.

[16] Because $z_{max} = 0.8$, we have $P_0 = 1/0.8 = 1.25$. However, at $P = 1.25$, $v < 0$. For v to be positive, we require $u_0 \leq \frac{(Pz_0)^2}{1+Pz_0}$ which gives $P \geq 1.28$.

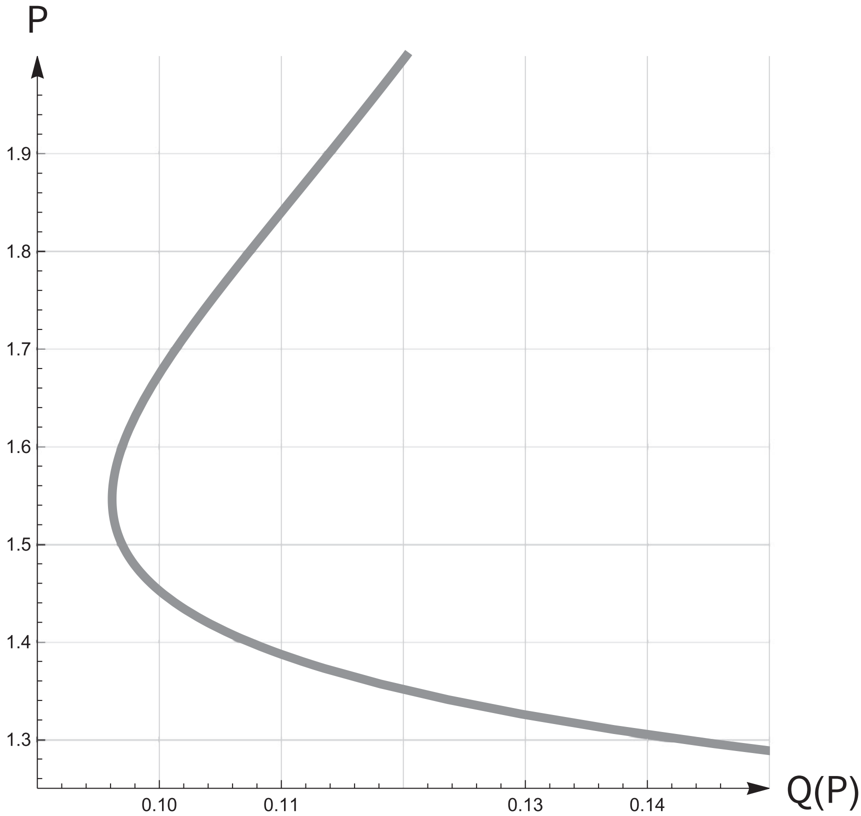

Figure 4

A Non-Monotonic Industry Supply.

Notes: The OAS is downward-sloping for low levels of market price, whereas it is upward-sloping for high price levels.

A few caveats related to Example 1 are worth mentioning. First, the density of z is skewed to the right so that high-productivity enterprises are relatively abundant. With a left-skewed density of z, the OAS can still be non-monotonic, but the downward-sloping portion reduces. In the above example, about 36% of the entire range of price variation attributes to the downward-sloping part of the OAS, whereas with shape parameters (0.5, 1), it is about 22%. Clearly, for different parameter configurations, the OAS can also be entirely downward-sloping (e.g., under the same parameter configurations, with $u_0 = 0.35$ instead of 0.25). Second, we have assumed that, at all prices, the highest-productivity enterprise generates revenue greater than 1, i.e., $Pz_{max} \geq 1$. If we had allowed the price to fall below $P_0 = 1/z_{max}$, there would have been an equilibrium where all enterprises chose to stay separate and the industry supply was upward sloping for prices $P < P_0$. Thus the OAS is actually *backward bending* on $(0, P_{max}]$. In Appendix B, we analyze other types of equilibria. Especially, for $P > P_{max}$, a non-monotonic equilibrium in which low-and high-productivity enterprises choose to integrate whereas medium-productivity enterprises choose to stay separate emerges. In Proposition 5, we show that, under sufficiently tractable conditions, the probability of integration is either increasing or decreasing in price. The associated OAS can thus be non-monotonic. An important takeaway of Proposition 3 is that a non-monotonic supply curve may exist even if the equilibrium ownership structure is monotonic.

V(iii). *Free Entry: Effect on Integration and the Long-Run OAS*

Our model so far has a fixed mass of firms on both sides of the input market. We now extend the analysis to allow for entry of firms in the long-run. There is a fixed cost of entry $\tau > 0$ for all A firms, whereas the entry cost of the B firms is normalized to zero. Suppose at an initial price P, A firms break-even. Recall also that a B firm earns u_0 in the lowest-productivity enterprise z_0. When the product market price goes up, strictly positive profits [for the A unit] at this enterprise will attract entry of new A firms. To balance the input market, a positive mass of B firms will enter with productivities less than b_0.

Entry at the bottom will continue at a given price P until the profits of the A firms dissipate. Hence, in the free-entry equilibrium, the productivity of the least productive B units becomes a function of the market price, i.e., $b_0(P)$. Write $z_0(P) = az(b_0(P))$. We continue assuming that the lowest-productivity enterprise following entry will stay separate. Thus, $z_0(P)$ is determined by solving the following zero-profit condition:

$$\phi^N(z_0, u_0, P) = \tau.$$

Note that differentiation of the above condition with respect to P yields $dz_0/dP < 0$.

V(iii)(a). *Effect of Entry on Integration*

Because the lowest-productivity B unit following entry consumes u_0, the least productive B firm prior to entry would obtain utility strictly higher than u_0. As a result the utility of each B unit goes up, and the common utility level of the A firms reduces ($v(P)$ shifts down parallelly). By contrast, the indifference loci would remain the same for all incumbent enterprises. This makes the utility allocation in all incumbent enterprises even more unbalanced in favor of the B units. Therefore, the indifferent enterprise in the short-run equilibrium, $z^*(P)$ moves to integration in the long-run. However, there is a countervailing force of entry in favor of non-integration. The least productive enterprises, which are now more in number, choose to stay separate. Therefore, the effect of entry at the bottom on the incidence of integration is ambiguous.

V(iii)(b). *The Long-Run OAS*

The aggregate industry output surely increases in the long-run due to an increased number of enterprises in the input market following entry. The long-run OAS is similar to the short-run where z_0 is replaced by $z_0(P)$. Let the unique indifferent enterprise in the long-run equilibrium be denoted by $z^{**}(P) \leq z^{*}(P)$. Differentiating the aggregate industry output with respect to price we obtain

$$Q'(P) = \underbrace{-g(z_0(P))q^N(z_0(P), P) \cdot \frac{dz_0(P)}{dP}}_{(+)} - g(z^{**}(P))[q^I(z^{**}(P), P) - q^N(z^{**}(P), P] \cdot \frac{dz^{**}(P)}{dP} + \int_{z_0(P)}^{z^{**}(P)} \frac{\partial q^N(z, P)}{\partial P} g(z)dz.$$

Relative to the expression for the slope of the OAS in the short-run [cf., expression (8)], there is an additional term (the first term of the above expression) that is positive, and captures the effect of entry of lower-productivity enterprises. Clearly, this reduces the range of price variation over which the OAS may be downward-sloping. Moreover, whenever the industry supply in the long-run is upward-sloping, it is more elastic relative to the short-run. By contrast, whenever the industry supply in the long-run is downward-sloping, it is steeper than that in the short-run because of the positive effect entry has on the output of the non-integrated firms. To summarize,

Proposition 4. Relative to the short-run, in the long-run following free entry at the bottom, (a) the aggregate industry output is higher; (b) the downward-sloping segment of the OAS continues being a possibility although this segment shrinks; and (c) the upward-sloping part becomes more elastic, whereas the downward-sloping segment (if it exists) becomes less elastic.

VI. EMPIRICAL RELEVANCE

There are two strands of the extant empirical literature that analyze the relationship between product market prices (broadly, competition) and firm boundary decisions. One kind, recent and scant, analyzes the causal effect of an increase in the intensity of competition on decision to integrate in vertically related markets. Alfaro, Conconi, Fadinger and Newman [2016] find, using a large cross-country, cross-industry firm-level data set, that the incidence of integration increases with the price level. They use changes in tariffs as an exogenous source of price variation. McGowan [2017] also finds negative association between the degree competition (as measured by reduction in transportation costs) and vertical integration in a study of the U.S.

coal mining industry. A railroad deregulation policy that induced transportation costs to fall made the coal mining industry more competitive, and lowered the incidence of integration. Both the aforementioned papers rely on explanations similar to the one offered by Legros and Newman [2013], i.e., augmented revenue due to increased prices reduces the opportunity cost of integration, and hence, an exogenous increase in price induces more firms to vertically integrate. By contrast, Stiebale and Vencappa [2018], in a study of Indian industries, draw a negative association between price and integration. A possible explanation is that [domestic] firms vertically integrate in order to enhance productivity to survive increased foreign competition. A change in the country's trade policy (e.g., tariffs) has been the source of exogenous price variation. However, unlike Alfaro *et al*. [2016], these authors assume imperfect competition in the retail markets.

A few other works analyze the relationship between competition and vertical integration, although the explanations are based on non-price variables related to the degree of competition. Aghion, Griffith and Howitt [2006] show a possible U-shaped relationship between competition and the incidence of integration. Acemoglu, Aghion, Griffith and Zilibotti [2010] analyze the causal effect of increased competition on firm boundary decisions. Examining plant-level data for the U.K. manufacturing sector, they show that increased upstream competition (as measured by the number of firms) that reduces the outside option of the upstream suppliers increases the likelihood of vertical integration, whereas increased downstream competition lowers the incidence of integration.

Proposition 2 thus takes exception to the popular view that increased competition necessarily leads to less integration, and offers a novel testable implication pertaining to how a change in product market competition triggers industrywide organizational restructuring.

Implication 1. There are ranges of values of revenue of the lowest-productivity enterprise, R_0 and reservation utility, u_0 such that the relationship between product market competition (as measured by the price level) and the incidence of integration is inverted-U shaped.

As low prices are equivalent to more intense competition (at least under the assumption of perfectly competitive product market), an inverted-U relationship between competition and integration is equivalent to an inverted-U shaped $z^*(P)$. The following numerical example confirms the above assertion.

Example 2. We assume $z_0 = 0.5$ and $u_0 = 0.21$. The range of variation of the product market price is [1.25, 2]. Note that at $P_0 = 1/0.8 = 1.25$, feasibility is satisfied because $v(P_0) > 0$. Figure 5 depicts the indifferent enterprise $z^*(P)$ at each P which is inverted U-shaped with respect to price.

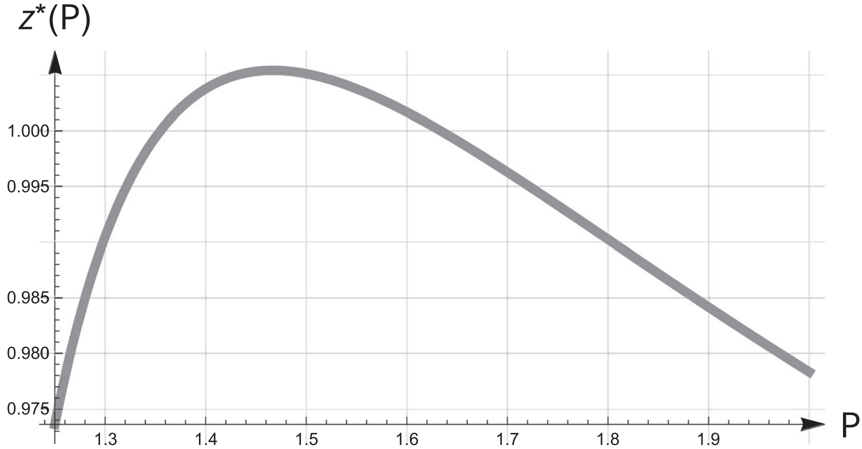

Figure 5

An Inverted-U Relationship between Competition and Incidence of Integration

Thus, integration is increasing for low levels of competition, and decreasing for more high levels of competition.

Depending on the parameter values, $z^*(P)$ can be monotonic or non-monotonic with respect to market price. The sufficient condition (6) in Proposition 2 under which there is a positive association between price and integration holds for low values of u_0, whereas condition (7) holds for high values of u_0 (See Figure 9 in Appendix B). Thus, an inverted-U is more likely to emerge for intermediate values of reservation utility of the B firms. The values of reservation utility u_0 may be high because the assets of the B units are highly valuable in other markets.

The other strand of empirical literature has dealt with the reverse causality as it has analyzed the effect of vertical integration on [retail] market prices, which is principally motivated by the efficiency effect of integration, such as more productive firms tend to integrate more (e.g., Hortaçsu and Syverson [2007]) or vertical mergers imply cost reduction via the elimination of double marginalization (e.g., Gil [2015]). A negative association between vertical integration and retail prices is likely to arise because of the efficiency gains of vertical mergers.

The aforementioned empirical literature finds evidence of correlation among price, output and integration. Hortaçsu and Syverson [2007], in a study of the U.S. cement and ready-mix concrete industries, show that between 1982 and 1992 vertical integration rose from 32.5% to 49% accompanied by a rise in sales from 49.5% to 75.1%. They do not find anticompetitive effects of vertical merger as the retail prices have fallen during this period owing to an increase in efficiency due to the expansion of larger, more productive firms at the expense of the less productive ones who charged higher prices. Gil (2015] studies the pricing policy of 393 theaters in 26 American cities between 1945 and 1955, and finds that vertically integrated theaters charged lower prices and sold more admission tickets than their non-integrated counterparts. By contrast, McGowan [2017] shows positive correlation among price, quantity and integration (a fall in the market price by 32% has been accompanied by a 33% decrease in the incidence of integration and a 43% reduction in quantity purchased by the upstream firms in the U.S. coal mining industry in the 1980's). Proposition 3 offers another important testable implication regarding the correlation among price, quantity and integration.

Implication 2. The organizationally augmented supply curve can be downward-sloping, and hence, following a negative demand shock, there is a decrease in the equilibrium product market price accompanied by an increase in the incidence of integration and output.

The above implication is described in Figure 6. A negative demand shock shifts the demand for the retail good from D to D'. Because the industry supply is downward-sloping, price reduces from P to P', and quantity increases

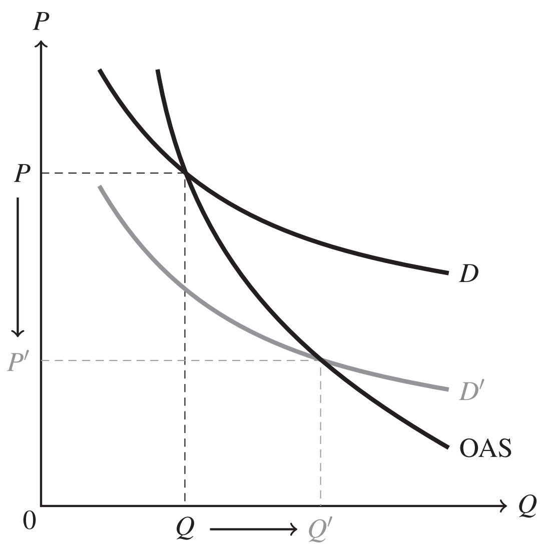

Figure 6

The Product Market Demand Decreases from D to D'

Notes: Because the OAS is downward-sloping, price reduces to P' and market output increases to Q'. Moreover, a downward-sloping OAS implies that integration must increase following the reduction in price.

from Q to Q'. Because price reduction must imply more integration, the above implication holds.

McGowan [2017] argues that his finding is consistent with an inward shift of the demand curve in the regional coal market. By contrast, we predict that a decrease in demand leads to integration and output being negatively correlated with price because the demand curve may intersect the OAS at its downward-sloping portion. Implication 2 thus offers an explanation based on organizational restructuring following an exogenous change in retail prices, which is complementary to the one offered by Hortaçsu and Syverson [2007] and Gil [2015].

VII. CONCLUSION

We analyze the determinants of firm boundaries when heterogeneous enterprises interact in a perfectly competitive product market. The model offers three important implications—(i) there is robust coexistence of diverse ownership structures (integration and non-integration) in the same input market, (ii) there may an inverted-U shaped relationship between competition and integration, and (iii) an exogenous reduction in demand leads to lower product market price, higher output and more integration because the organizationally augmented industry supply curve may have an downward-sloping segment.

The choice of ownership structure in a given enterprise depends on the trade-off between the benefits from coordination and private costs—non-integration, a mode based on contingent revenue shares, puts too much weight on the private costs of managerial actions and hinders coordination; integration, which is based on delegation of decision rights to an outsider, facilitates coordination but ignores private costs. Neither mode of organization thus achieves full efficiency. Unbalanced utilities (due to unbalanced revenue shares) between the two units induce the managers to opt for integration because coordination is poor if they remain separate. Balanced utilities, on the other hand, harmonize incentives, and make non-integration more likely to dominate.

When firms on one side of the input market are vertically ranked with respect to productivity, competition for high-quality units arises naturally. We model such competition as a two-sided matching game, which endogenizes revenue share or utility allocation in each enterprise. Thus, *ex ante* differences in input productivity imply *ex post* differences in firm revenue. Moreover, high-revenue enterprises opt to integrate because the incentive to coordinate is high in such firms, whereas low-revenue enterprises stay separate.

The present model also yields interesting implications with respect to *managerial firms*. When managers are partial revenue claimants, they tend to underweight enterprise revenues in favor of private costs because the perceived price is lower than the actual market price. Essentially, the impact of partial revenue claims by the managers on ownership structures is similar to the impact market price has when firms are non-managerial. The presence of managerial firms thus yields an equilibrium that is organizationally inefficient (e.g., Leibenstein [1966]) because the true market price (that reflects the social value of output) is unchanged, the decision to integrate depends on the fraction of the price that accrues to managers, and the equilibrium analyzed in the present context is efficient. Thus, the presence of managerial firms may imply either 'too little' or 'too much' integration in equilibrium relative to the social optimum under non-managerial firms. This can have interesting policy implications related to corporate governance. Stronger (weaker) CEO incentives, if it applies uniformly across all firms, can be viewed as equivalent to a higher (lower) price in our base model with no managerial firms, which may result in more (less) integration. If there is already too little (much) integration from the social perspective, then stronger (weaker) incentives can be welfare-enhancing. In the latter case, a cap on CEO pay may be a policy tool.[17] Thus, analyzing the implications of managerial firms with respect to firm boundary decisions is on our agenda for future research.

APPENDIX A

PROOFS

We omit the analysis of Section III (choice of ownership structure for a given enterprise) because it is very similar to that in Legros and Newman [2013]. They consider a fixed success output 1 for all enterprises. We instead have z. Thus, we can replace P in the Legros and Newman [2013] model by $R \equiv Pz$ to obtain all the expressions associated with the optimal contract of a given enterprise z.

Proof of Proposition 1. Because of our assumption that enterprise z_0 always has N as the dominant choice, we have $v \leq R_0^2/(1+R_0)$, otherwise feasibility would be violated. Further, $R_0^2/(1+R_0) \leq 0.5$ because $z_0 \leq z_1$. As v is constant, it always lies below the indifference locus IL^+, and hence, the indifferent enterprise $z^*(P)$ cannot lie on IL^+. Note that $v_L(z_0) \leq 0$ because for enterprise z_0, N strictly dominates I. On the other hand, $v \geq 0$. Thus, $v_L(z_0) - v \leq 0$. Moreover, $v_L(z) - v$ is strictly increasing in z. There are two possibilities. First, $v_L(z_{max}) - v \geq 0$. In this case the Intermediate Value Theorem and monotonicity of $v_L(z) - v$ with respect to z together imply that $z^* \in (z_0, z_{max})$ exists and unique. The second possibility is that $v_L(z_{max}) - v \leq 0$. Because $v_L(z) - v$ is strictly increasing in z, we have $v_L(z) - v \leq 0$ for all $z \in [z_0, z_{max}]$, and hence, all enterprises choose N in equilibrium. ■

Proof of Proposition 2. Solving (5) we get

$$z^*(P) = \frac{1+4v(P)+\sqrt{(1+4v(P))(9+4v(P))}}{4P}.$$

[17] Furthermore, taxes can also have implications on the efficiency of organizational choice that are similar to a price change.

The ambiguity of the effect of price change on integration comes from the fact that both the numerator and denominator of the above expression are strictly increasing in P because $v'(P) > 0$. The sufficient conditions (6) and (7) may appear to be strong—however, weaker conditions are hard to derive as the the sign of $dz^*(P)/dP$ is very difficult to determine analytically. In what follows, we analyze these sufficient conditions. Note first that condition (6) is implied by:

$$\text{(A1)} \qquad \begin{aligned} &v'(P) = \frac{\partial \phi^N}{\partial P}(z_0, u_0, P) \leq \frac{\partial v_L}{\partial P}\left(z_1(P), P\right) \\ &\iff R_0\left(\frac{2R_0[R_0(2+R_0)-2u_0]}{\sqrt{R_0^2(2+R_0)^2-4(1+R_0)^2u_0}} + \frac{\sqrt{R_0^2(2+R_0)^2-4(1+R_0)^2u_0}}{(1+R_0)^2} - 2R_0\right) \leq \frac{3}{8}, \end{aligned}$$

where $z_1(P) = 1/P$ and $R_0 \equiv Pz_0$. Let

$$S^+ \equiv \left\{ (R_0, u_0) \mid u_0 \leq \frac{R_0^2}{1+R_0} \text{ and } (R_0, u_0) \text{ satisfies } (A1) \right\}.$$

In Figure 7, on the vertical axis, we plot the values of u_0, the reservation utility of the B firms, and on the horizontal axis, we have the revenue of the lowest-productivity enterprise for all feasible combinations of P and z_0, i.e., $R_0 \leq 1$. We allow u_0 to vary between 0 and 0.5 because u_0 must be strictly less than the maximum surplus of enterprise $z_1(P)$, which is 0.5. In reality, feasibility dictates that $u_0 \leq R_0^2/(1+R_0)$ which is the entire area under the convex function in Figure 7. The set S^+ is given by the region labeled S^+, which is clearly non-empty.

Next, let $z_{max} = z_0 + x$, and consider condition (7) which is implied by:

$$\text{(A2)} \qquad v'(P) = \frac{\partial \phi^N}{\partial P}(z_0, u_0, P) \geq \frac{\partial v_L}{\partial P}\left(z_0 + x, P\right).$$

Let

$$S^* \equiv \left\{ (z_0, x, u_0, P) \mid u_0 \leq \frac{R_0^2}{1+R_0} \text{ and } (z_0, x, u_0, P) \text{ satisfies } (A2) \right\}.$$

Note that the assumption $Pz_{max} = P(z_0 + x) \geq 1 = Pz_1(P)$ is equivalent to $x \geq z_1(P) - z_0$, and at $x = z_1(P) - z_0$, condition (A2) is complementary to (A1), which is given by the region labeled S^-, and is the largest possible [non-empty] set over which (A2) holds, i.e., $S^* = S^-$. Because the difference between $v_L(z, P') - v_L(z, P)$ is strictly increasing in z, for any $x > z_1(P) - z_0$, we have $S^* \subset S^-$. The set S^* shrinks as x grows rendering condition (A2) harder to hold. For sufficiently high x, the inequality in (A2) does not hold anymore, i.e., $S^* = \emptyset$. In other words, there are values of $x > z_1(P) - z_0$, not very large, for which condition (A2) holds, and hence, $S^* \neq \emptyset$. It is worth noting that the regions S^+ and S^- in Figure 7 are derived analytically.

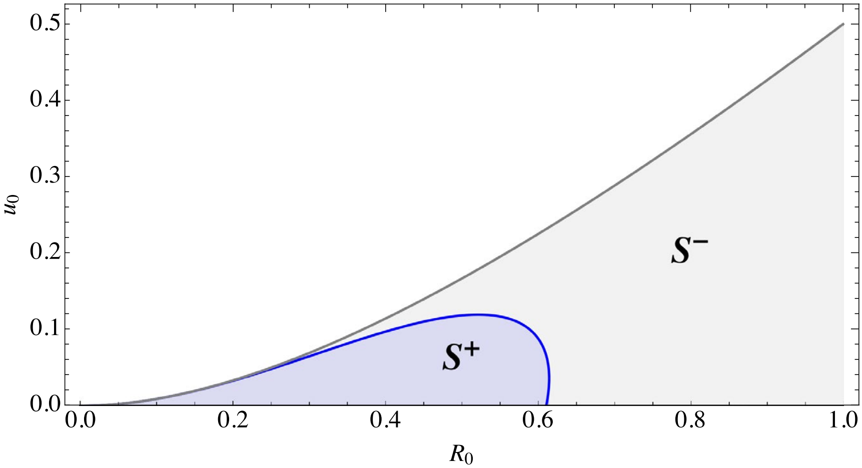

Figure 7

Notes: On S^+, condition (6) holds, and hence, higher price implies more integration. On the other hand, S^*, the set over which there is a negative association between price and integration is a subset of S^-. [Colour figure can be viewed at *wileyonlinelibrary.com*]

Nonetheless, we omit the analytical expressions for the restrictions on (R_0, u_0) as they are lengthy and cumbersome. ■

APPENDIX B

MORE EQUILIBRIA

We have mentioned earlier that there might be equilibria different from the one described in Proposition 1, which we analyze below. First, consider the case when $P < P_0 = 1/z_{max}$. In this case N is a strictly dominant choice even for the highest-productivity enterprise z_{max}. Thus for any distribution of surplus, all enterprises $z \in [z_0, z_{max}]$ choose non-integration.

Next, consider $P > P_{max} = 1/z_0$. In this case, for no enterprise N is a strictly dominant choice. There are many possible equilibria depending on the share of surplus between the A and B units in each enterprise, which are depicted in Figure 8.

The value of z_0, i.e., the position of the bargaining frontier of this enterprise is important in determining the type of equilibria that emerges when $P > P_{max}$. The frontier labeled z_0 is drawn such that $Pz_0 > 1 = Pz_1(P)$. Three types of equilibria are possible. First, consider a low v equal to v_1. In this case, the utility allocation is very unbalanced in favor of the B firm in enterprise z_0, and hence, this enterprise chooses to integrate. As a consequence, all enterprises $z \in [z_0, z_{max}]$ integrate. Next, consider an intermediate value v_2 of the utility of the A firms. In this case, the equilibrium is monotone with low-productivity enterprises choosing N and the high-productivity ones choosing I. Of course, if z_{max} is not sufficiently high, then all enterprises would choose N. Finally, consider a high v such as v_3. Now the share of revenue is very unbalanced in favor of the A unit in the lowest-productivity enterprise z_0, and hence, this enterprise

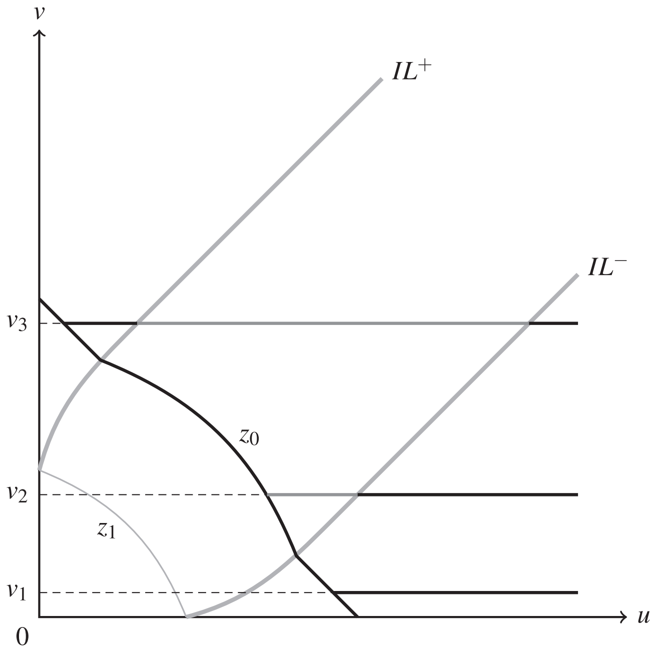

Figure 8

Many Equilibria when $P > P_{max}$.

Notes: At $v = v_1$, all enterprises choose *I*; at $v = v_2$, the equilibrium ownership structure is monotonic with low-productivity enterprises choosing *N* and the high-productivity ones choosing *I*. For $v = v_3$, the equilibrium ownership structure is non-monotonic in that low- and high-productivity enterprises choose *I*, and the intermediate-productivity ones choose *N*.

chooses *I*. The horizontal line v_3 intersects the indifferent loci twice, once at IL^+ and again at IL^-. The equilibrium ownership structure is non-monotonic—low- and high-productivity enterprises choose *I* while the enterprises with intermediate levels of productivity choose *N*. Again, if z_{max} is not too high such that $v_L(z_{max}) < v_3$, then the structure is monotone where the low-productivity enterprises choose *I* and the high-productivity enterprises choose *N*. Note that, in all three situations, *v* is such that it is feasible for all the enterprises (the horizontal line at v_3 starts from a point lower than the maximum surplus of the lowest-productivity enterprise), and $v_1 \geq 0$.

Price-integration relationship. We analyze the price-integration relationship when $P > P_{max}$. In particular, we consider the case of non-monotonic equilibrium when $v = v_3$. We assume that v_3 does not depend on the product market price (either *A* firms are on the long side of the market or the lowest-productivity *B* firm receives all the incremental surplus for some exogenous reason). The equilibrium in this case, and the effect of price increase are presented in Figure 9 which is similar to Figure 3, except that now there are two indifference loci, $v_H(z, P)$ and $v_L(z, P)$ to be considered. Because $z_0 \geq z_1(P)$, both $v_L(z_0, P)$ and $v_H(z_0, P)$ are positive numbers at

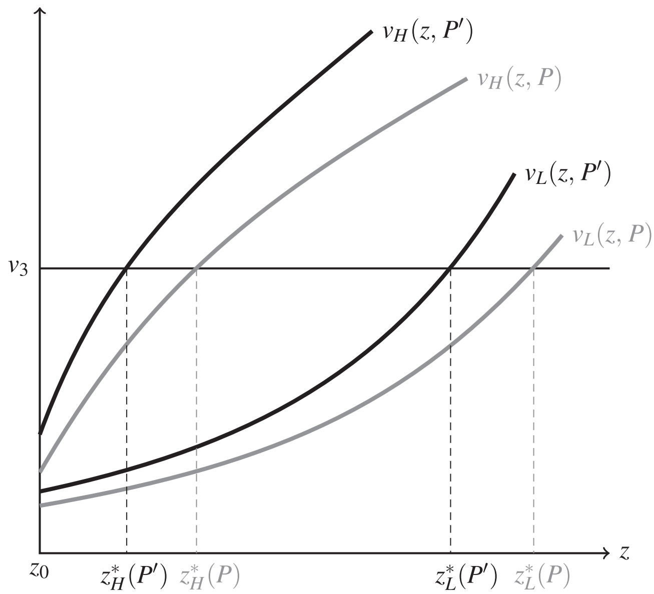

Figure 9

Notes: A price increase shifts both $v_L(z, P)$ and $v_H(z, P)$ up; however, v_3 is unaffected. As a result, both $z^*_H(P)$ and $z^*_L(P)$ go down.

any P (they start at the vertical axis). There are two indifferent enterprises at the initial price P—namely, $z^*_H(P)$ and $z^*_L(P)$ with $z^*_H(P) < z^*_L(P)$ for all $P > P_{max}$. The probability of integration at the initial product market price is given by $G(z^*_H(P)) + 1 - G(z^*_L(P))$.

At the higher price P', both loci shift up. The indifferent enterprises are given by $z^*_H(P')$ and $z^*_L(P')$. Note that the probability of integration decreases at $z^*_H(P)$ by $G(z^*_H(P)) - G(z^*_H(P'))$, but it increases at $z^*_L(P)$ by $G(z^*_L(P)) - G(z^*_L(P'))$. Hence, the effect of price increase on integration is *a priori* ambiguous.

Proposition 5. The effect of an exogenous increase in the product market price on the probability of integration is in general ambiguous. If $g(z)$ is decreasing (increasing) on $[z_0, z_{max}]$, then there is a negative (positive) association between price and integration.

Proof. We first argue that $z^*_L(P) - z^*_L(P') = z^*_H(P) - z^*_H(P')$ for all P and P' with $P' > P$. Recall that $z^*_L(P)$ and $z^*_H(P)$ respectively solve

$$v_L(z, P) = \frac{(Pz-1)(1+2Pz)}{4(1+Pz)} = v_3, \quad \text{and} \quad v_H(z, P) = \frac{2(Pz)^2 + 3Pz - 1}{4(1+Pz)} = v_3.$$

Because P and z enter both functions $v_L(z, P)$ and $v_H(z, P)$ multiplicatively, and both are strictly increasing in P and z, a unit increase in P must imply the same decrease in z in order to keep both v_L and v_H at the constant level v_3. Now integration decreases with price if and only if

$$\begin{aligned} & G(z_L^*(P)) - G(z_L^*(P')) \leq G(z_H^*(P)) - G(z_H^*(P')) \\ \Longleftrightarrow\ & g(z_L^*(P'))[z_L^*(P) - z_L^*(P')] \leq g(z_H^*(P'))[z_H^*(P) - z_H^*(P')] \\ \Longleftrightarrow\ & g(z_L^*(P')) \leq g(z_H^*(P')) \end{aligned}$$

because $z_L^*(P) - z_L^*(P') = z_H^*(P) - z_H^*(P')$. Note that if $g(z)$ is decreasing (increasing) in z, then $g(z_L^*(P)) \leq (\geq) g(z_H^*(P))$ for any $P > P_{max}$. This completes the proof of the proposition. □

The above condition is intuitive. If $g(z)$ is decreasing in z, then $g(z_L^*(P)) \leq g(z_H^*(P))$ at any P. Therefore, integration decreases following a price increase because more enterprises move from I to N [at $z_H^*(P)$] than N to I [at $z_L^*(P)$]. On the other hand, if $g(z)$ is increasing in z, then $g(z_L^*(P)) \geq g(z_H^*(P))$ at any P, and hence, there is a positive association between price and integration. One interesting case emerges when $g(z)$ is the uniform density. In this case, an increase in P does not induce any organizational restructuring, i.e., the probability of integration is constant with respect to the product market price. ■

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