CESifo Working Papers

INTEGRATION VS. OUTSOURCING IN INDUSTRY EQUILIBRIUM

Gene M. Grossman
Elhanan Helpman

CESifo Working Paper No. 460

April 2001

CESifo
Center for Economic Studies & Ifo Institute for Economic Research
Poschingerstr. 5, 81679 Munich, Germany
Tel.: +49 (89) 9224-1410
Fax: +49 (89) 9224-1409
e-mail: office@CESifo.de

CESifo *Working Paper No. 460*
April 2001

INTEGRATION VS. OUTSOURCING IN INDUSTRY EQUILIBRIUM

Abstract

We develop an equilibrium model of industrial structure in which the organization of firms is endogenous. Differentiated consumer products can be produced either by vertically integrated firms or by pairs of specialized companies. Production of each variety of consumer good requires a unique, specialized component. Vertically integrated firms can manufacture the components they need in the quantity and type that maximizes profits, but they face a relatively high cost due to diseconomies of scope. Specialized firms can produce at lower cost, but outsourcing imposes costs due to search frictions and imperfect contracting. We study the equilibrium mode of organization when inputs are fully or partially specialized. We consider how the degree of competition in the industry, the nature of the search technology, the division of bargaining strength between intermediate and final producers, and the sensitivity of manufacturing costs to input characteristics affect the equilibrium organizational form.

JEL Classification: D23, D43, D51.

Gene Grossman
International Economics Section
Department of Economics
Princeton University
Princeton, NJ 08544
USA
Grossman@princeton.edu

Elhanan Helpman
Eitan Berglas School of Economics
Tel Aviv University
Ramat Aviv
Tel Aviv 69978
Israel
Helpman@post.tau.ac.il

1 Introduction

The "make-or-buy" decision is fundamental to industrial organization. Hundreds of activities go into the sale of a finished product, from basic research to product design, from preparation and installation of machinery and the production of components, to assembly, packing, marketing and shipping. For each such activity, a producer must decide whether to undertake the activity in house or to purchase the input or service from outside. As Coase (1937) emphasized long ago, the cumulation of these decisions defines the boundaries of the firm.

Industrial organization has evolved over time. First, putting-out gave way to the factory system. Then dramatic changes in the organization of factories occurred with the advent of steam power and, later, electricity. Interchangeable parts enabled mass production as well as horizontal and vertical specialization. Now, advances in communication technology and in computer-aided design are again transforming the way production is organized.

An interesting trend has been noted in some recent research. In many sectors, firms are outsourcing inputs and services that formerly they would have been produced in house. For example, Abraham and Taylor (1996) provide evidence of rising outsourcing of business services in thirteen U.S. industries, while Helper (1991) documents the increased outsourcing of parts in the U.S. automobile sector. Signs of vertical disintegration also appear in the data on international trade. Audet (1996), Campa and Goldberg (1997), Hummels et al. (1998) and Yeats (1998) have used trade in intermediate inputs or in parts and components to measure what they variously termed 'vertical specialization', 'intra-product specialization' and 'global production sharing'. All these authors find rapid growth in specialization for a varied group of industries including textiles, apparel, footwear, industrial machinery, electrical equipment, transportation equipment, and chemicals and allied products.[1]

What accounts for the increasing degree of specialization in production? Which

[1] Ford et al. (1993) conducted a survey of purchasing managers in several countries. They report that more than two-thirds of U.S. respondents had indicated a recent rise in their input purchases, while less than one fifth reported a decline in purchases. Similar trends of increased outsourcing were reported for firms in the United Kingdom, Canada and Australia. See also McMillan (1995), who surveys the evidence on increased outsourcing and discusses possible explanations for these trends.

industries will be most affected and which stages of production? What are the consequences for economic efficiency and the implications for competition policies? An equilibrium model of industrial organization is needed to address these questions and others like them. The development of such a model is the aim of this paper.

In modeling the outsourcing decision, we emphasize a trade-off between the costs of running a larger and less specialized organization and costs that arise from search frictions and imperfect contracting. A vertically integrated firm may face a higher cost of producing components and services, because such a firm has many divisions to manage, and because the organization does not benefit from the learning that comes with specializing in a single activity. But a firm that opts to outsource its components must search for a suitable partner, and then try to provide this partner with incentives to produce inputs to its specifications and in the quantity it demands. Search is costly and does not always end in success. And contracting may be imperfect, if some attributes of the input are not verifiable by third parties.

Ours is hardly the first paper to point to imperfect contracts as an important element in firm's outsourcing decisions. Following the seminal work of Williamson (1975, 1985) and Grossman and Hart (1986), much research has been devoted to clarifying the roles of transaction costs, asset specificity, and incomplete contracts in guiding the choice between in-house production and outsourcing. This work has focused, however, on the bilateral relationship between a single producer and its potential supplier. As such, it is not fully suitable for analysis of industry trends, because the attractiveness of options available to a firm may well depend on the decisions taken by others.

In order to construct an equilibrium theory of industrial organization, we adopt a rudimentary approach to search frictions and contractual incompleteness, based on the early works in these areas by Diamond, Williamson and others. Our emphasis is not on the contract or search theory per se, but rather on the interdependencies in the outsourcing decisions of the firms in an industry. We seek to identify the feedback mechanisms by which the firms' behavior determines market conditions, which in turn influence an individual firm's choice of organizational form.[2]

[2] See McLaren (2000) for an interesting predecessor to this paper, which, however, was constructed to make a more narrow point.

We develop in the next section a simple, multi-industry model in which differentiated consumer products can be produced either by vertically integrated firms or by pairs of specialized companies. In the latter case, one firm manufactures an intermediate input while the other designs and assembles a variety of the final product. The production of each variety of consumer good requires a unique, specialized component. Vertically integrated firms manufacture their own components in the quantity and design that maximizes profits. However, such firms face relatively high fixed and variable production costs, due to their lack of complete specialization and the extra governance costs associated with their extensive organizations. Specialized firms may be able to produce at lower cost, but they suffer from two potential disadvantages. First, a specialized final good producer must find a suitable supplier of inputs, while a specialized component producer must find a potential customer. We model search as a matching process, in which some firms are successful in locating a partner and others are not. Second, the specialized firms may suffer from an inability to prove the quality and other attributes of an input to outside parties. This limits contracting possibilities and creates a potential hold-up problem.

In Section 3, we characterize the equilibrium modes of organization under the assumption that the search technology exhibits constant returns to scale. With constant returns in search, a doubling of the number of specialized firms of each type results in a doubling of the number of partnerships that are formed. We show that, except in a knife-edge case, there are no equilibria in which an industry is populated by both specialized and vertically integrated firms. We then discuss the conditions for the existence of an equilibrium with pervasive vertical integration and the conditions for the existence of one with pervasive outsourcing. We also discuss the stability of each type of industry equilibrium.

In Section 4, we identify the industry conditions that support vertical integration or outsourcing as the equilibrium mode of organization. We focus especially on how the degree of substitutability between an industry's consumer products and the distribution of bargaining power between intermediate and final-good producers affect the viability of each organizational form. In this section, we also show that neither the size of an industry nor the size of the aggregate economy favors one mode of industrial organization over the other. However, this finding is modified in Section 5, where we consider search technologies with increasing returns to scale. If there are increasing returns in search, there can be two stable equilibria for an industry, one with vertical integration and the other with pervasive outsourcing. Outsourcing is more likely to be viable, the larger is the industry and the larger the economy.

Finally, in Section 6, we extend the model to allow for a secondary market in intermediate inputs. The simple model overstates the hold-up problem for many industries, because we assume that input producers have no option to sell their wares to any firm other than the one for whom the components were designed. In reality, specialization typically occurs in stages, and it is often possible to recoup some of the investment if it becomes necessary to find a new business partner. To capture this idea, we introduce components that differ in their degree of specialization. We associate with each final good an ideal component, which is the one most suitable for producing that good. But final producers can use inputs of different specifications at an additional cost. Now the bargaining between supplier and final producer takes place against a backdrop in which each side has an outside option.

In the extended model, component producers choose the degree to which they specialize their inputs for their prospective customers. A more specialized input offers greater profit opportunities in its intended use. But a more generic input enhances outside options and so improves the input producer's bargaining power. In equilibrium, the producer strikes a balance between the opposing forces, and manufactures a component that is partially specialized. We describe the determinants of the equilibrium degree of specialization and the mode of organization. Here we consider a new factor, which is the sensitivity of manufacturing costs of final goods to the specifications of the component.

The last section contains some concluding remarks.

2 A Simple Model

We begin with a simple version of our model. In the simplified model, intermediate inputs must be fully tailored to a particular product or else they are worthless to the final producer. With this assumption, an input producer has no choice but to sell its output to the firm for whom it was designed. Later, we will allow final producers to use components that are not built exactly to their specifications. Then we will treat the degree of specialization as a choice variable for the input providers.

The economy has J industries. In each industry, firms produce a continuum of different varieties. The representative consumer maximizes a utility function of the form

$$u = \sum_{j=1}^{J} \mu_j \log \left[\int_0^{N_j} y_j(i)^{\alpha_j} di \right]^{\frac{1}{\alpha_j}}, \tag{1}$$

where $y_j(i)$ is consumption of variety i in industry j and N_j is the number (measure) of differentiated varieties produced by that industry. We assume that $\sum_j \mu_j = 1$, so that the parameter μ_j gives the share of spending that a consumer devotes to products of industry j. The parameter $\alpha_j \in (0,1)$ measures the degree of product differentiation in industry j; the greater is α_j, the less differentiated are the outputs of the industry. There is a unit measure of consumers.

As is well known, these preferences yield demand functions,

$$y_j(i) = A_j p_j(i)^{-\frac{1}{1-\alpha_j}}, \tag{2}$$

where $p_j(i)$ is the price of good i in industry j,

$$A_j = \frac{\mu_j E}{\int_0^{N_j} p_j(i)^{-\frac{\alpha_j}{1-\alpha_j}} di},$$

and E is aggregate spending. The unique supplier of variety i in industry j treats A_j as a constant, and so perceives a constant elasticity of demand $1/(1-\alpha_j)$. Aggregate spending equals national income in the general equilibrium.

The production of a unit of any final good requires one unit of a specialized component. For now, the component must be exact in its specifications and the different final goods require distinct components. An input must also be of suitably high quality or else it is useless for producing final output. Besides the intermediate goods, there are no other variable inputs into final production. However, there are fixed costs associated with entering the market and searching for a potential supplier.

Final goods may be produced by vertically integrated firms or by specialized producers that purchase their inputs at arms length. A firm that specializes in manufacturing intermediates can produce a high quality input with one unit of labor per unit of output. Alternatively, it can produce a low quality (and therefore useless) input at some lower cost. An integrated firm in industry j requires $\lambda_j \geq 1$ units of labor to produce a unit of the (high quality) intermediate. The possibility that production may be more costly for an integrated firm reflects the fact that its activities are not so highly specialized and that the bureaucratic cost of managing a larger operation may be higher.[3]

As for the fixed costs, these may vary by type of firm and mode of organization. The total fixed input required of a vertically integrated firm in industry j is k_{jv} units of labor. This includes the resources needed to enter the market (e.g., researching the market opportunities and setting up an organization), those needed to design a product, and those necessary for corporate governance. The fixed input requirement for a specialized producer of intermediates in industry j is k_{jm} units of labor. This includes elements that are analogous to those for a vertically integrated firm, and also the resources required to search for a potential partner. A specialized producer of final goods in industry j has a fixed input requirement of k_{js} units of labor, which similarly includes a search component. We assume that the fixed costs for an integrated firm are no lower than those for a pair of specialized producers; i.e., $k_{js} + k_{jm} \leq k_{jv}$.

Our setting is one with incomplete contracting. We suppose that the quality of an intermediate input can be observed by the collaborating partners, but cannot be verified by a court of law. The lack of verifiability precludes contracts between input suppliers and potential customers that stipulate a given price for an agreed quantity. If such a contract were signed, an intermediate producer could lower its costs by shaving quality. The buyer would be obliged to buy the inferior products without recourse. Much has been written about possible alternatives to quality-contingent contracts in contexts such as ours. For example, Aghion et al. (1994) argue that specific-performance contracts coupled with certain renegotiation schemes sometimes

[3] Williamson (1985) emphasized that production by a vertically integrated firm may entail greater governance costs due to attenuated incentives and bureaucratic distortions. McAfee and McMillan (1995) have developed a formal model that bears on this claim. In their model, employees with private information are organized in a hierarchical structure. The employees capture informational rents, which cumulate along the hierarchy. They find that production costs are increasing in the length of a firm's hierarchical structure. More generally, there may be some diseconomies of scope that are independent of the volume of output and others that affect per unit costs. We allow for both types of extra costs here.

can be used to promote efficient relationship-specific investments. Maskin and Tirole (1999) suggest alternative contract contingencies; in our economy, for example, a final-good producer might agree to compensate its component supplier based on the revenues received from sales of the final product. Since the final producer has no moral hazard in choosing its assembly or marketing efforts, the intermediate producer can be given the appropriate incentive to invest in quality. In response, Hart (1995), Segal (1999) and Hart and Moore (1999) have argued that there are settings in which these various fixes for incomplete contracts fail. We have nothing new to add to the debate about the foundations of incomplete contracts; we simply assume that they are a fact of commercial life.

The absence of *ex ante* contracts creates a potential hold-up problem, as is well known from the writings of Williamson (1985), Klein et al. (1978), Hart (1995), and others. Once a component producer specializes its production for a particular final good, these inputs have no value to other firms. The final producer can threaten to refuse delivery of the components unless the price is sufficiently low. But an *ex post* negotiation of the price leaves the intermediate producer in a relatively weak bargaining position, because the manufacturing costs are bygones by that time. Foreseeing this prospect, the intermediate producer has insufficient incentive to produce the efficient quantity. The inefficiency that results from the hold-up problem gives a reason for vertical integration, which must be weighed against any excess production and governance costs that such an organizational structure might entail.[4]

Having described the technology for production and the limitations on contracting, we detail the sequence of events in the economy. First, firms enter as either intermediate producers, final-good producers, or vertically-integrated entities. In each case, an entrant pays the relevant entry cost. Next, the specialized firms search for partners. A firm that has entered as a specialized component producer seeks a

[4] As is well known, the possibility of repeat business can mitigate the hold-up problem to some degree. An input supplier might produce high-quality components even if it is not bound to do so by an enforceable contact, in order to establish a good reputation with the buyer. Similarly, the buyer might pay a "fair" price for the inputs, even when it could capture short-term gains by behaving opportunistically. In many situations, however, the prospect of repeated interaction will not fully solve the hold-up problem. We choose to keep our model simple and stark by focusing on a one-shot game.

producer of final-goods to serve with inputs. A manufacturer of finished goods seeks an input provider. Matches occur randomly. We assume that every specialized producer of final goods has the same probability of finding a supplier. Similarly, every potential producer of components has the same probability of finding a customer. The two probabilities are not equal, however; firms on the "short end" of the market have a greater chance of achieving a match.[5] The search frictions and associated uncertainties give a second advantage to vertical integration.

When specialized firms are paired in a match, the final-good producer describes its input requirements. Then all integrated firms and component producers manufacture their specialized inputs. These may be of high quality or of low quality, and they may be produced in any quantity. Firms that have failed in their search efforts have no choice but to exit the market. Next, the specialized input producers bring their components to their potential customers, and the partners negotiate over the terms of trade. Bargaining results in the input producer in industry j capturing a fraction ω_j of the surplus in its relationship with the final producer. We take the bargaining weights to be exogenous. After the negotiations have been concluded and the inputs turned over to the final-goods producers, these producers and the vertically integrated firms assemble their differentiated varieties. Finally, the goods are sold to consumers.

To summarize, firms play a game with the following five stages: (1) entry, at which time a portion of the fixed costs are incurred; (2) search, at which time the remaining fixed costs are incurred and firms that do not find partners exit the market; (3) production of intermediate inputs; (4) bargaining; and (5) production and sale of final goods. In this setting, we seek a general equilibrium in which the aggregate labor market and all product markets clear. Free entry ensures zero expected profits for each type of firm that enters a market.[6] If some type of firm does not enter in equilibrium, then its expected profits must be zero or negative. The supply of labor

[5] In principle, a firm might enter as vertically integrated and nonetheless seek a potential partner. Then, if it fails to achieve a match, it can produce its own inputs. Even if it finds a partner, it might produce some inputs itself, in order to strengthen its bargaining position. However, these strategies will not be profitable if the search costs and the manufacturing costs are sufficiently high. We assume a cost structure such that vertically integrated firms will not wish to search for suppliers, without dwelling on the implied parameter restrictions.

[6] The matching process creates risk for specialized producers. But the households hold diversified portfolios of equities, so the firms maximize expected profits.

is fixed and equal to L. We choose labor as the numeraire, so that the wage rate is equal to one.

Now we consider the profitability of the different types of firms that might enter in industry j. Since we will focus for the time being on this single industry, we omit the index j from the industry-specific variables.

Let v be the number of firms that enter as vertically-integrated enterprises, s, the number that enter as specialized producers of final goods, and m, the number that enter as specialized suppliers of intermediate products. The specialized producers of final goods seek partners among the potential input producers and *vice versa*. Not all firms are successful in their searches. We assume that $n(s,m)$ pairings are formed, where $n(s,m) \leq \min\{s,m\}$ and $n(\cdot)$ is increasing in both of its arguments. For the most part, we will assume constant-returns-to-scale in matching; i.e., a doubling in the number of firms on each side of the market results in a doubling in the number of partnerships. But the case of increasing returns is also of interest, so we will consider it separately in Section 5.[7]

Since all specialized producers of final goods have the same chance of finding a partner, the probability of being matched is $n(s,m)/s$ for each one. Assuming that matching has constant returns to scale, we can rewrite this probability as $\eta(r) \equiv n(1,r)$, where $r = m/s$ is the ratio of specialized component producers to specialized final producers. Similarly, since all intermediate-good producers have the same chance of finding a partner, each has a probability $n(s,m)/m = \eta(r)/r$ of realizing a match. Note that the elasticity of $\eta(\cdot)$ must be smaller than one, in view of the linear homogeneity of $n(\cdot)$. Thus, the probability $\eta(r)$ increases with r, while the probability $\eta(r)/r$ declines with r.

Consider what happens after a match takes place between a certain intermediate-good producer and a firm that has developed a certain differentiated product, say

[7] Matching functions are commonly used in the analysis of job search; see, for example, Pissaridis (1990, 2000). Blanchard and Diamond (1989) find that the matching of workers and vacancies exhibits constant returns to scale in macro data. Coles and Smith (1996) corroborate the Blanchard-Diamond findings using micro data. Lagos (2000) develops a spatial model of matching between buyers and sellers, which also implies constant returns to scale in matching. But increasing returns can arise if a concentration of searchers in a given geographic area makes finding a match easier for all parties.

good i. If the input provider produces $x(i)$ units of the specified component, its partner will have the ability to produce $y(i) = x(i)$ units of variety i. The potential revenue from sales of these goods is $p(i)x(i)$. Once the $x(i)$ units of the intermediate good have been manufactured, the two firms meet to negotiate an exchange. At this point, all costs are sunk. If the exchange takes place, the final producer stands to realize revenues of $p(i)x(i)$. If, instead, the firms go their separate ways, revenues for each side are zero. This is because the final producer has no alternative source for components, while the intermediate producer has a quantity of specialized inputs that is of no value to any other producer. It follows that the exchange generates a joint surplus of $p(i)x(i)$. In the bargain, the firms divide this surplus, with a share ω going to the producer of intermediates and the rest to the final producer.

Now roll back the clock to the time when the intermediate firm must decide how much to produce and of what quality. The firm foresees a potential reward of $\omega p(i)x(i)$ from producing $x(i)$ units of a high-quality component. This it could do at a variable cost of $x(i)$. If, instead, it produces low-quality components, no transaction will occur and all manufacturing costs will be lost. The intermediate firm maximizes profits by choosing to produce high quality and, in view of the demand function (2), by setting $y(i) = x(i) = A\left(\alpha\omega\right)^{1/(1-\alpha)}$. All prices are the same in a symmetric equilibrium. Therefore, the price of a final good sold by a specialized producer is

$$p_s = \frac{1}{\alpha\omega} \tag{3}$$

and the resulting sales are

$$y_s = A\left(\alpha\omega\right)^{\frac{1}{1-\alpha}}. \tag{4}$$

The price ultimately charged for goods assembled by firms that outsource their components is $1/\omega$ times as much as what a unitary actor with a unit cost of one would charge. The diminished output and higher price reflect the distortionary impact of the imperfect contract.[8]

A final-good producer realizes operating profits equal to a fraction $1-\omega$ of its revenues of $p_s y_s$. An entrant obtains these profits if and only if it finds a partner,

[8] This distortion is analogous to the "double marginalization" that arises when an input supplier with market power prices at above marginal cost and then the final producer, also with market power, introduces an additional mark-up. Double marginalization provides an incentive for vertical integration in markets with perfect contracts; see, for example, Perry (1989).

which happens with probability $\eta(r)$. Therefore, the expected profits of a specialized producer of final goods are

$$\pi_s = \eta(r)(1-\omega) A (\alpha\omega)^{\frac{\alpha}{1-\alpha}} - k_s \ , \tag{5}$$

after taking account of the fixed costs of entry and search.

An intermediate-good producer captures operating profits equal to a fraction ω of the revenue from sales of the final good less production costs, or $\omega p_s y_s - y_s$. An entrant obtains these profits with probability $\eta(r)/r$. Therefore, expected profits for a specialized producer of intermediate inputs are

$$\pi_m = (1-\alpha) \frac{\eta(r)}{r} \omega A (\alpha\omega)^{\frac{\alpha}{1-\alpha}} - k_m \ , \tag{6}$$

again after accounting for fixed costs.

Notice the positive relationship between the number of one type of specialized producer and the potential profits of the other. Given an industry demand level A, the expected profits of a specialized final-good producer are greater the larger is the number of specialized input suppliers, because an increase in the number of potential suppliers improves the prospects for a given final-goods producer to find a partner. The expected profits of a specialized input supplier increase with the number of specialized producers of final goods for the same reason. But the expected profits of each type of producer decline with entry of other firms like it, because additional firms on the same side of the market reduce the likelihood of a match for each one. This, of course, is a stabilizing force. A second stabilizing influence comes through adjustments in the demand factor A, which reflects competition among the final-good producers.

A vertically integrated firm faces a marginal production cost of λ and a demand curve given by (2). The constant demand elasticity dictates mark-up pricing, with a profit-maximizing price of

$$p_v = \frac{\lambda}{\alpha}. \tag{7}$$

The resulting sales of a vertically integrated firm are

$$y_v = A \left(\frac{\alpha}{\lambda}\right)^{\frac{1}{1-\alpha}} . \tag{8}$$

Operating profits of such a firm, which equal revenue less input production costs, are $p_v y_v - \lambda y_v$. Therefore, at the entry stage, the firm's expected profits are given by

$$\pi_v = (1-\alpha)\, A \left(\frac{\alpha}{\lambda}\right)^{\frac{\alpha}{1-\alpha}} - k_v. \tag{9}$$

In equilibrium, no firm has positive expected profits; i.e., $\pi_\ell \leq 0$ for $\ell = v, s, m$. Moreover, expected profits are zero for any type of firm that enters in positive number. With aggregate profits equal to zero, aggregate income and aggregate spending are equal to the aggregate wage bill, L. It follows from the definition of A_j in (2) and our pricing equations (3) and (7), that the industry demand level is given by

$$A = \frac{\mu L}{v\left(\frac{\alpha}{\lambda}\right)^{\frac{\alpha}{1-\alpha}} + s\eta\left(r\right)\left(\alpha\omega\right)^{\frac{\alpha}{1-\alpha}}}. \tag{10}$$

This completes our discussion of the profit opportunities in industry j.

There are two channels through which firms interact in our model. First, the final-good producers compete in the product market. This affects not only the profitability of final production, but also of specialized input producers, who share in the revenues from downstream sales. Second, specialized firms on each side of the market compete for partners, while firms on opposite sides of the market provide complementary services. These sorts of interactions are the focus of our equilibrium analysis. These considerations would be absent, of course, from an analysis that addressed only the incentives facing a pair of firms.

3 Types of Equilibria

Three types of outcomes may characterize the organization of firms in our model: the firms in an industry may all be vertically integrated; the firms in an industry may all be specialized producers; or vertically integrated firms and specialized producers may compete in the same industry. We argue in this section that an industry is unlikely to be populated by firms with different organizational forms. Then we identify conditions under which there is a stable industry equilibrium with pervasive vertical integration or with pervasive outsourcing of intermediates.

3.1 Mixed Equilibrium

We first examine conditions for the existence of an industry equilibrium in which both vertically integrated firms and specialized firms are active in the marketplace. For this outcome to materialize, there must be positive values of v, s and m for which the expected profits of all three types of firms are equal to zero.

If both $\pi_s = 0$ and $\pi_m = 0$, we have two equations that provide a unique solution for the industry demand level A and the relative number of firms $r = m/s$. Using (5) and (6), we see that both specialized intermediate producers and specialized final-goods producers will expect to break even if and only if

$$r_O = \frac{\omega(1-\alpha)}{1-\omega}\frac{k_s}{k_m} \tag{11}$$

and

$$A_O = \frac{(\alpha\omega)^{-\frac{\alpha}{1-\alpha}}k_m}{\omega(1-\alpha)}\frac{r_O}{\eta(r_O)}, \tag{12}$$

where the subscript "O" indicates a variable relating to an equilibrium in which firms engage in outsourcing.

Meanwhile, using (9), we see that a vertically integrated firm earns zero profits if and only if the industry demand level is

$$A_I = \frac{\left(\frac{\lambda}{\alpha}\right)^{\frac{\alpha}{1-\alpha}}k_v}{1-\alpha}. \tag{13}$$

The two demand levels — A_O (required for the viability of outsourcing) and A_I (required for the viability of vertical integration) — are incompatible with one another, except in a knife-edge case. Unless the industry parameters happen to produce $A_O = A_I$, at least one type of firm will face conditions that are adverse to entry. We have thus shown that

Proposition 1 *Generically, no industry has both vertically integrated and specialized producers.*

This finding reflects our assumption that all potential entrants of a given type are identical. If we had assumed that some vertically-integrated firms can produce components at lower cost than others, it might be possible for these especially efficient firms to enter profitably alongside firms that are specialized in producing components

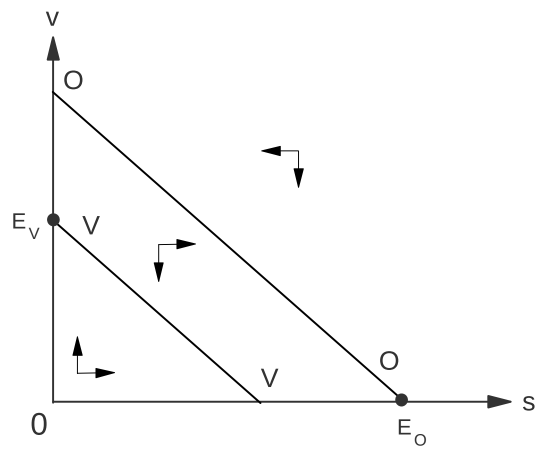

Figure 1: Equilibrium curves: $A_I > A_O$

or final goods. Our result also relies on the assumption of constant returns to scale in matching. With decreasing returns to matching, specialized firms might be profitable if relatively few of them enter, but unprofitable if many of them choose to enter. Then the industry might be populated by a moderate number of specialized firms and some firms that are vertically integrated. But the empirical evidence suggests that matching has constant or slightly increasing returns to scale, and so does not support an assumption that would lead to organizational diversity.

There is another way to understand Proposition 1. In figure 1, we show the combinations of numbers of specialized final-good producers and vertically integrated firms that are consistent with zero expected profits for a typical one of each of these firms, when specialized intermediate and final-good producers enter in the ratio r_O. The line OO depicts combinations of s and v that imply $\pi_s = 0$. These combinations satisfy[9]

$$v\left(\frac{\alpha}{\lambda}\right)^{\frac{\alpha}{1-\alpha}} + s\eta\left(r_O\right)\left(\alpha\omega\right)^{\frac{\alpha}{1-\alpha}} = \frac{\mu L}{A_O}\ . \tag{14}$$

Similarly, the line VV depicts combinations of s and v that imply $\pi_v = 0$. The

[9]Given an entry ratio r_O, the specialized final-good producers will earn zero expected profits if and only if the industry demand level is A_O. Equation (14) gives the combinations of s and v that yield the required level of industry demand, in view of (10).

equation for this line is given by

$$v\left(\frac{\alpha}{\lambda}\right)^{\frac{\alpha}{1-\alpha}}+s\eta\left(r_O\right)\left(\alpha\omega\right)^{\frac{\alpha}{1-\alpha}}=\frac{\mu L}{A_I}. \tag{15}$$

Figure 1 depicts the case where $A_I > A_O$; then, OO lies outside of VV. In any case, the two lines are parallel. This means that no combination of s and v yields zero profits for both types of firms, unless the lines happen to coincide. Entry by one type of firm in numbers that ensure zero expected profits guarantees losses for the other.

The question that remains is, When will an industry organize with vertically integrated firms and when with specialized producers that outsource their components? A response to this question will help us to predict the cross-sectoral variation in modes of organization. Intuitively, competition at the entry stage favors the mode of organization that is viable with a lower level of industry demand. We develop this intuition in the next two sections.

3.2 Vertical Integration

We now consider equilibria in which all firms that enter some industry j are vertically integrated. We argue that economy-wide equilibria with this property always exist. However, an equilibrium with vertically integrated firms in industry j will be stable if and only if $A_I < A_O$ in that industry.

When all firms are vertically integrated, we have a standard situation of monopolistic competition. The conditions for equilibria of this sort are familiar from the work of Dixit and Stiglitz (1977) and others. Prices and output levels are given by (7) and (8). Free entry implies zero profits, which means that $A = A_I$. Then, with $s = m = 0$, (13) and (10) imply that the equilibrium number of integrated firms is

$$v_I=\frac{(1-\alpha)\mu L}{k_v}. \tag{16}$$

For this to be an industry equilibrium, it must be that no firm wishes to enter as a specialized producer of intermediate goods or as a specialized producer of final goods. But given that $s = m = 0$, were a single firm to enter as a specialized producer, it would find no counterpart on the other side of the market with which to interact. Such a firm would search in vain for a partner and ultimately forfeit its entry fee. Thus, an industry equilibrium with $v = v_I$ and $s = m = 0$ can always be sustained.

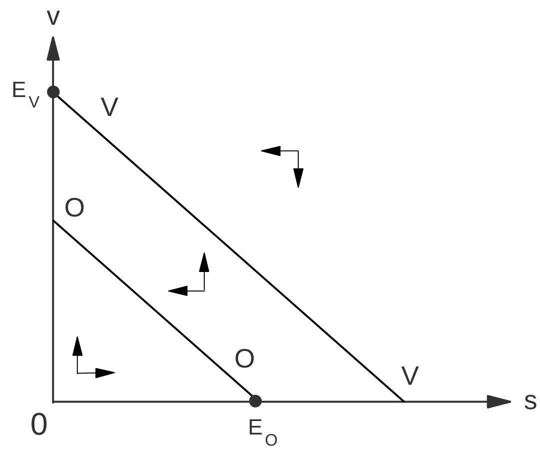

Figure 2: Equilibrium curves: $A_I < A_O$

Although equilibria with vertically integrated firms in industry j exist for all parameter values, such equilibria may not be stable. To discuss stability, we need to specify out-of-equilibrium dynamics. In our context, the most natural process to consider is one in which firms of a particular type enter the industry when they expect to earn positive profits and exit when they foresee expected losses.

Recall that figure 1 depicts a setting with $A_I > A_O$. With the indicated dynamics, specialized producers enter at all points below the OO line and exit at all points above this line, while vertically integrated firms enter at all points below the VV line and exit at all points above this line. Thus, the arrows in the figure describe the evolution in the number of firms.[10] It is clear that point E_V in figure 1 — which represents an outcome with $s = 0$ and $v = v_I$ — is not stable. Any perturbation of the equilibrium triggers dynamics that lead the industry to diverge from this point.

Figure 2 depicts a situation with $A_I < A_O$. Now the VV line is above the OO line, and the industry equilibrium with pervasive integration is at point E_V. This

[10] Since the industry potentially has three different types of firms, the dynamic analysis ought to be conducted in a three-dimensional space. Our discussion in the text is limited to situations in which entry and exit of specialized producers of intermediate and final goods occur in the fixed proportions r_O. We do this for expositional convenience only, because the two-dimensional analysis provides a simpler (and correct) intuition. We have carried out the three-dimensional stability analysis and find that it yields the same conclusions. This analysis is contained in Appendix 1.

equilibrium is stable. We have therefore established[11]

Proposition 2 *There always exists an equilibrium with vertical integration in industry j. The industry equilibrium is stable if and only if $A_I < A_O$ for industry j.*

3.3 Pervasive Outsourcing

Pervasive outsourcing requires that $r = r_O$ and $A = A_O$, with $v = 0$. It follows from (10), (11), (12) and (14) that

$$s_O = \frac{(1-\omega)\,\mu L}{k_s} \tag{17}$$

and

$$m_O = \frac{(1-\alpha)\,\omega\mu L}{k_m}. \tag{18}$$

Evidently, the larger is the industry (as measured by μ) or the economy (as measured by L), the greater is the number of specialized firms of each type that enters the industry. The larger are the fixed costs, the smaller is the number of firms. The division of bargaining power affects the incentives for entry in opposite ways; the greater is the share of the surplus that goes to intermediate-good producers, the greater is entry by this type of firm and the smaller is the entry of specialized final-good producers. Finally, the greater is the substitutability between an industry's products, the smaller is the number of firms that enter to produce specialized components. Variation in α has no effect on the number of firms that enter as specialized producers of the final goods. The reason for this asymmetry is that, due to the imperfect contracting, the component producers bear all of the cost of manufacturing the intermediate inputs. As a result, the final-good producers earn as profits a fraction of revenues, which, in equilibrium, are invariant to the elasticity of demand. But the intermediate producers capture the remaining fraction of revenues less the variable costs, an amount that does depend on the elasticity of substitution between final goods. If contracting were not a problem (i.e., if the quality of inputs were verifiable and therefore contractible ex ante), then the substitutability of final goods would affect the profitability of both types of producers and therefore the numbers of each type of entrant.

[11] Note that, in the knife-edge case of $A_I = A_O$, the coincidence of OO and VV implies the existence of a continuum of equilibria. In this case, the assumed dynamics dictate that the outcome will vary with the initial conditions.

For the existence of an equilibrium with $s = s_O$, $m = m_O$ and $v = 0$, it must be the case that potential entry is not attractive to any vertically integrated producer. Such an entrant would anticipate an industry demand level A_O. Its expected profits are negative if and only if $A_O < A_I$, since A_I is the minimum level required for these firms to break even It follows that there exist equilibria with pervasive outsourcing in industry j if and only if $A_I \geq A_O$. Such an industry equilibrium is represented by the point E_O in figure 1. From the figure, we can see that the equilibrium with pervasive outsourcing is stable, whenever $A_I > A_O$. We have thus proved[12]

Proposition 3 *There exist equilibria with pervasive outsourcing in industry j if and only if $A_I \geq A_O$ for industry j. The industry equilibrium is stable if $A_I > A_O$.*

4 Equilibrium Mode of Organization

We now examine in detail the factors that determine the equilibrium mode of organization in an industry. As we have seen, this amounts to a comparison of A_I and A_O. Factors that favor outsourcing are those that increase the ratio A_I/A_O, where

$$\frac{A_I}{A_O} = \omega \left(\lambda\omega\right)^{\frac{\alpha}{1-\alpha}} \frac{\eta\left(r_O\right)}{r_O} \frac{k_v}{k_m} \tag{19}$$

and

$$r_O = \frac{\omega(1-\alpha)}{(1-\omega)} \frac{k_s}{k_m}$$

as given by (11).

Not surprisingly, pervasive outsourcing is a more likely outcome in an industry the greater is λ, the cost advantage of specialized component producers relative to vertically integrated firms. Similarly, the greater are the fixed costs for vertically integrated firms and the smaller are the fixed costs for the two types of specialized producers, the more likely is outsourcing to be an equilibrium outcome. An efficient search technology also favors outsourcing; the larger is $n(\cdot)$ for given values of s and m, the greater is $\eta(r_O)/r_O$ and thus the greater is A_I/A_O. In equilibrium, an

[12] Formally, we must also check that a firm would not wish to enter as an integrated firm, search for an entrant, produce a quantity of its own intermediates, and then purchase additional intermediates from its partner. It is straightforward to show that, with $k_v \geq k_s + k_m$, this strategy never is profitable.

improvement in the search technology does not affect s_O, m_O, or the ratio of the two. But it does raise the probability that any given entrant will find a partner. This reduces the level of industry demand necessary for a typical specialized firm to break even.

With constant returns to scale in matching, neither the share of spending devoted to an industry's output nor the overall size of the economy has any effect on the likelihood that outsourcing will be the equilibrium mode of organization. As we will see in the next section, this conclusion is dependent on the properties of the search technology; with increasing returns to matching, larger industries are more likely to be organized into specialized firms.

The interesting part of Proposition 3 concerns the roles of the parameters α and ω in determining the equilibrium mode of organization. Let us begin with α, the parameter that describes the degree of substitutability between an industry's final goods. If α is close to one, the industry's goods are nearly perfect substitutes and the industry is highly competitive. If α is close to zero, consumers regard the industry's goods as distinct products and each producer enjoys substantial monopoly power.

As can be seen in equation (19), there are two distinct channels by which the substitution parameter affects the relative profitability of the alternate modes of organization. For a given ratio r_O, an increase in α increases A_I/A_O if and only if $\lambda\omega > 1$. To understand this effect, recall that $p_v = \lambda/\alpha$ and $p_s = 1/\omega\alpha$, so that $p_v/p_s = \lambda\omega$. If $\lambda\omega > 1$, specialized final producers would sell their output at a lower price than would their vertically integrated counterparts. Then the potential operating profits of the specialized firms would be relatively greater, the greater is the elasticity of demand. If $\lambda\omega < 1$, it is the vertically integrated producers who would sell their output at a lower price, and then the relative operating profit of the specialized producers falls with the elasticity of demand. The comparison of λ with $1/\omega$ is a comparison of the cost disadvantage that reflects the diseconomies of scope with the distortion that results from the imperfect contracting. With an imperfect contract, the specialized component producer receives only a fraction ω of the operating profits, but bears the full cost of producing the inputs. Therefore, this firm produces less than the joint-profit maximizing volume of output, causing an elevated price of the final good.

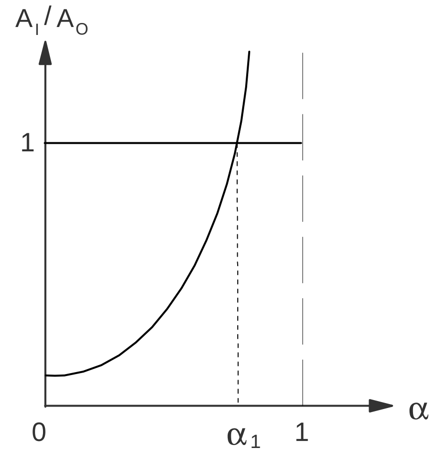

Figure 3: Industry organization for $\lambda\omega > 1$: The role of the elasticity of substitution

The degree of substitutability between final products also affects A_I and A_O through its influence on the fraction of revenues that producers are able to capture as operating profits. With vertical integration, operating profits are a fraction $1-\alpha$ of revenues, so potential profits fall (given revenues) as α rises. With outsourcing, the operating profits of a component producer are a fraction $\omega(1-\alpha)$ of revenues, so these producers too face lower potential earnings the greater is α. Since the potential profitability of each type of firm is reduced in the same proportion, there is no net effect on the ratio A_I/A_O on this account.

But there is one more channel by which the degree of substitutability affects the relative viability of the alternative modes of organization. Recall that α plays a role in determining the number of specialized intermediate producers that enters the industry in an equilibrium with outsourcing; the more substitutable are the final products, the smaller is m_O. With less entry by intermediate producers (and an unchanged s_O), the probability that any such entrant will find a partner increases. This reduces the level of industry demand needed for a specialized component producer to have zero expected profits, given the operating profits it can anticipate if it is successful in its search for a partner. In terms of equation (19), an increase in α reduces r_O, thereby increasing $\eta(r_O)/r_O$ and A_I/A_O.

Figure 3 shows the relationship between the elasticity of substitution and the ratio

A_I/A_O for the case where $\lambda\omega > 1$. As we have indicated, when $p_s < p_v$, an increase in α raises the relative operating profits of specialized producers. It also increases the probability that a given intermediate producer will find a partner. For both reasons, A_I/A_O rises with α, which means that an increase in the elasticity of substitution increases the relatively viability of outsourcing. A stable equilibrium with pervasive outsourcing exists if and only if $A_I/A_O > 1$; in the figure, this is true for $\alpha > \alpha_1$. For $\alpha < \alpha_1$, there is a stable industry equilibrium in which all firms are vertically integrated.

Now consider an industry in which $\lambda\omega < 1$. In such an industry, the relative operating profits of an integrated firm are higher, the greater is the elasticity of demand for a typical final good. But an increase in α also reduces the ratio of the number of specialized intermediate producers to the number of specialized final producers, thereby raising the likelihood that a typical component producer will find a partner. As we have seen, this boosts the likelihood that outsourcing will emerge as the equilibrium mode of organization.

Since these two forces pull in opposite directions, the net effect of a change in α depends upon which is stronger. Figure 4 depicts two possibilities. In panel a, the ratio A_I/A_O is a monotonically decreasing function of α. This case arises when the probability that a given component producer will find a match does not change very much with changes in the ratio of specialized intermediate producers to specialized final producers. Then the direct effect of α on the profitability of integrated versus final goods will dominate the effect of the change in $\eta(r)/r$, and vertical integration is more attractive in industries with a high degree of substitution. Note that, in the circumstances depicted in panel a, outsourcing can emerge in equilibrium only when $\alpha < \alpha_2$.

Panel b depicts an industry in which the probability of a match for a typical component producer responds more sensitively to changes in r. Here, the ratio A_I/A_O increases with α for a range of low values of α, and falls with α when α is large. Then — depending on the height of the curve — vertical integration may be an equilibrium outcome for a range of low and high values of the α, while pervasive outsourcing is a stable outcome when α falls in an intermediate range. The figure illustrates an example of this; specialized production is viable if and only if α falls between α_3 and

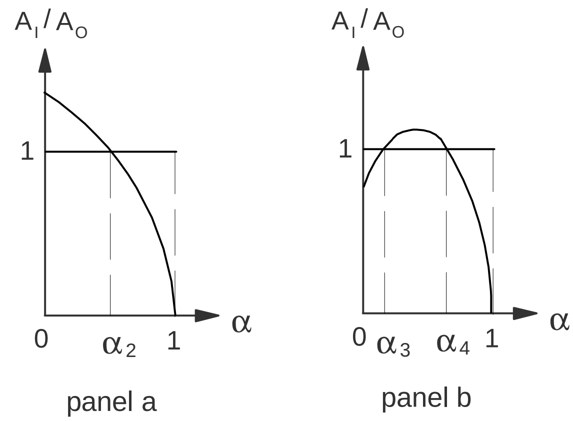

Figure 4: Industry organization for $\lambda\omega < 1$: The role of the elasticity of substitution

α_4.

To better understand these different possibilities, we calculate how the right-hand side of (19) varies with α. We find that A_I/A_O increases with α if and only if

$$1 - \varepsilon_\eta > -\frac{\log(\lambda\omega)}{1-\alpha}, \tag{20}$$

where ε_η is the elasticity of $\eta(r)$ with respect to r.[13] When $\lambda\omega > 1$, the right-hand side of (20) is negative, and thus the inequality must be satisfied. This is the case depicted in figure 3. When $\lambda\omega < 1$, the right-hand side (20) is positive and tends to infinity as α approaches one. Since, with constant returns in matching, the elasticity ε_η must fall between zero and one, the curve must be downward sloping when α is close to one, and it will be downward sloping for all values of α if $1 - \varepsilon_\eta$ is small enough.[14]

Next we discuss how the distribution of bargaining power affects the likelihood that outsourcing will be viable as an equilibrium organizational form. We find that

[13] Note that the probability of a match for a component producer is given by $\eta(r)/r$, which has an elasticity of $\varepsilon_\eta - 1$. Thus, the probability of a match for a component producer will be unresponsive to changes in r when ε_η is close to one.

[14] As an example, consider the matching function $n(s,m) = sm/(s+m)$. For this technology, $\eta(r) = r/(1+r)$ and $\varepsilon_\eta = 1/(1+r)$. Then, for $\lambda\omega < 1$, the A_I/A_O curve is everywhere downward sloping as in panel a when $\log(\lambda\omega) < -\omega k_s/(1-\omega)(k_s+k_m)$, and it has an inverted-U shape as in panel b when $\log(\lambda\omega) > -\omega k_s/(1-\omega)(k_s+k_m)$.

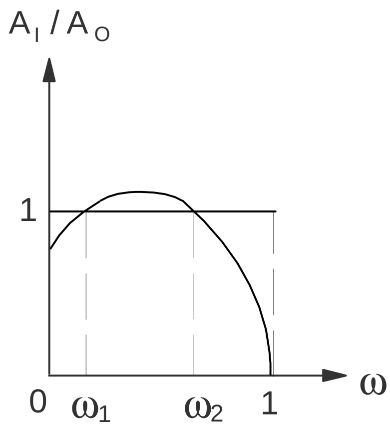

Figure 5: Industry organization: The role of bargaining power

changes in the division of surplus affect the ratio A_I/A_O in three ways. First, an increase in ω directly increases the profit share of specialized component producers, which tends to reduce the industry demand level needed for these firms to break even. Second, an increase in ω shrinks the distortion caused by imperfect contracting. This too increases the profitability of specialized input producers. But an increase in the bargaining power of intermediate-good producers causes the relative number of these firms to increase, which means that the typical such producer would have lower odds of finding a partner. This effect of an increase in ω tends to increase A_I/A_O.

Using (19), we calculate that A_I/A_O increases with ω if and only if

$$\varepsilon_\eta > \frac{\omega - \alpha}{1 - \alpha}.$$

At $\omega = 0$, the condition is violated, because $\varepsilon_\eta > 0$. At $\omega = 1$, the condition is satisfied, because $\varepsilon_\eta < 1$. Therefore, the relationship between A_I/A_O and ω has an inverted-U shape, such as the one depicted in figure 5. A very low or a very high value of ω points to vertical integration as the equilibrium mode of organization, whereas pervasive outsourcing is the unique stable outcome when ω falls in an intermediate range.

Intuitively, if ω is very small, the component producers would have little incentive to produce intermediates, and the cost of the final goods produced by specialized firms would be very high. If ω is very large, there would be many more component producers attracted to the industry than specialized producers of final goods, and each component producer would have little chance of finding a partner. Thus, outsourcing is sustainable in an industry equilibrium only if the bargaining power of the intermediate producers is neither too high nor too low.

5 Increasing Returns to Matching

Empirical studies of search have focused primarily on labor markets and the matching of workers and firms. This research suggests a search technology with constant or slightly increasing returns to scale. In business-to-business ("B2B") matching that is our concern here, the evidence is more indirect and anecdotal. We notice that firms in a given line of business often locate in the same small neighborhood of a big city. One will find in New York City, for example, a textile district, a diamond district, a furniture district, etc. It might seem surprising at first that firms would want to be near their rivals, in view of the intense competition that could result. But increasing returns in search could readily explain this phenomenon. Similarly, an increasing-returns search technology might explain why firms in markets of different sizes opt for different modes of organization. Indeed, when Chinitz (1961) compared the industrial structure in New York City and Pittsburgh, he found that firms in the former city were much more specialized than those in the latter. He attributed this difference to agglomeration economies such as could arise from increasing returns to matching.[15]

In this section, we revisit the determination of the equilibrium mode of organization in a setting where the search technology has increasing returns. Recall that $n(s, m)$ gives the number of partnerships that are formed when s specialized final producers search for potential input providers and m component producers search for potential customers. We now assume that $n(\cdot)$ is characterized by increasing returns in its two arguments, while continuing to take the probability of a match to be the same for all firms on a given side of the market.

With increasing returns to matching, we must rewrite the expressions for the potential profits of specialized firms. Analogous to (5) and (6), specialized final-good

[15] We thank Ed Glaeser for drawing our attention to Chinitz's findings.

producers see expected profits of

$$\pi_s = \frac{n(s,m)}{s}(1-\omega)A(\alpha\omega)^{\frac{\alpha}{1-\alpha}} - k_s \ , \tag{5'}$$

while specialized component producers perceive expected profits of

$$\pi_m = \frac{n(s,m)}{m}(1-\alpha)\omega A(\alpha\omega)^{\frac{\alpha}{1-\alpha}} - k_m \ . \tag{6'}$$

Industry demand now is given by

$$A = \frac{\mu L}{v\left(\frac{\alpha}{\lambda}\right)^{\frac{\alpha}{1-\alpha}} + n(s,m)\,(\alpha\omega)^{\frac{\alpha}{1-\alpha}}} \ . \tag{10'}$$

Using (5′) and (6′), we find that for both types of specialized producers to earn zero expected profits, we still require the ratio of intermediate to final producers to be $r_O = \omega(1-\alpha)k_s/(1-\omega)k_m$. However, the level of industry demand needed for the viability of these types of firms must be expressed differently, as

$$A_O = \frac{(\alpha\omega)^{-\frac{\alpha}{1-\alpha}}\,k_m}{\omega\,(1-\alpha)}\frac{r_O s}{n\,(s, r_O s)} \ . \tag{12'}$$

Notice that the required demand level now depends not only on the composition of entry, but also on the absolute number of firms that enter the market; for given r_O, the greater is s, the smaller is the demand level A_O needed for the two types of specialized firms to break even. This, of course, reflects the increasing returns to matching – when more firms enter on each side of the market, every firm has a better chance of finding a partner.

Recall figures 1 and 2, in which the line OO gives combinations of s and v consistent with zero expected profits for specialized final-good producers, conditional on the entry of specialized firms being in the proportions dictated by r_O. With increasing returns to matching, the modified equation for this curve (which no longer is linear) is given by

$$v\left(\frac{\alpha}{\lambda}\right)^{\frac{\alpha}{1-\alpha}} + n\,(s, r_O s)\,(\alpha\omega)^{\frac{\alpha}{1-\alpha}} = \frac{\mu L}{B}\frac{n\,(s, r_O s)}{r_O s} \ , \tag{14'}$$

where $B = (\alpha\omega)^{-\alpha/(1-\alpha)}\,k_m/\omega\,(1-\alpha)$. The line VV in figures 1 and 2 similarly gives combinations of s and v for which vertically-integrated firms break even. With increasing returns to matching, the equation for this curve becomes

$$v\left(\frac{\alpha}{\lambda}\right)^{\frac{\alpha}{1-\alpha}} + n\,(s, r_O s)\,(\alpha\omega)^{\frac{\alpha}{1-\alpha}} = \frac{\mu L}{A_I}. \tag{15'}$$

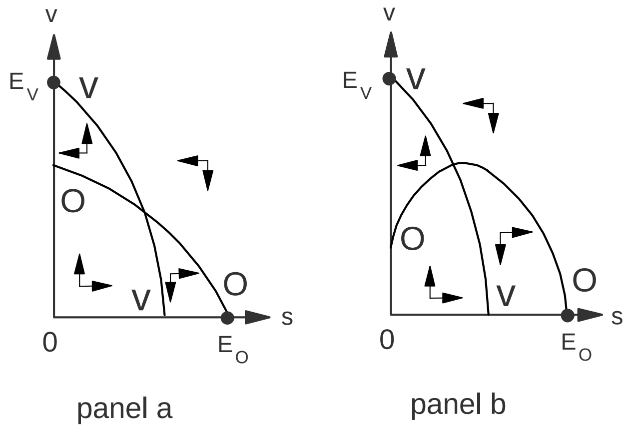

Figure 6: Increasing returns to matching: Multiple equilibria

Figure 6 shows the new VV curve and two possible shapes of the new OO curve. The VV curve is downward sloping, because the more crowded is the market with vertically-integrated firms, the smaller must be the number of competing specialized producers for an integrated firm to break even. The OO curve might also slope downward — as depicted in panel a — or it might slope upward and then downward — as depicted in panel b.[16] The curve will slope downward if the increasing returns to scale are slight. With stronger increasing returns, a rise in the number s of specialized final producers (together with the associated rise in the number of specialized component producers) may so improve the prospects for a given firm to find a match that its expected profits will grow, even considering the implied crowding of the product market. Then an increase in v would be needed to restore expected profits to zero.

In both panels of the figure, there is a mixed equilibrium in which vertically integrated firms and specialized firms coexist in the market. This equilibrium is found at the point of intersection of the OO curve and the VV curve. However, if the OO curve slopes downward, it must have a less negative slope then the VV curve at any point of intersection. This means that any mixed equilibrium will be unstable,

[16] Equation (14′) always has a solution with $v = 0$ and $s = (1 - \omega)\mu L/k_s$. The OO curve must slope downward in the neighborhood of this solution.

as can be seen from the dynamics indicated in the figure.

In each panel of figure 6, there are two additional equilibria that are denoted by E_V and E_O. E_V is an equilibrium in which all firms are vertically integrated. At E_O, all firms are specialized. In each case, both of these equilibria are locally stable. There are also some possibilities that are not shown in the figure. If industry conditions happen to be such that the VV curve lies everywhere above the OO curve, then there is a unique industry equilibrium in which all firms are vertically integrated. Alternatively, if conditions are such that the OO curve lies everywhere above the VV curve, then the only stable equilibrium is one with pervasive outsourcing.

We can now see how the size of an industry or the size of the economy can be a determinant of the equilibrium organizational form. As μL increases, the point of intersection of the VV curve and the horizontal axis shifts to the right in the same proportion, while the point of intersection of the OO curve and the horizontal axis shifts to the right less than proportionately. Therefore, an industry equilibrium with pervasive outsourcing is more likely to exist, the larger is the industry and the larger is the aggregate economy. Our model thus provides a possible explanation for the Chinitz (1961) finding; outsourcing may have been viable in New York City but not in Pittsburgh, because the scale of the former economy admitted a sufficient number of entrants for productive B2B search, whereas the scale of the latter economy did not. The model also is consistent with another possible explanation for the Chinitz findings. If conditions in each city were like those depicted in either panel of figure 6, the difference in industrial structure might have been an historical accident. When either mode of organization is viable, the equilibrium structure will depend on initial conditions and the vagaries of how potential entrants form their expectations about the intentions of others.

6 Partial Specialization

So far, we have assumed that an input must be tailored exactly to the specifications of a particular final good or else it is useless to the final producer. By making this assumption, we have eliminated all outside opportunities for producers on both sides of the market. An input supplier that has specialized a component for a particular end use has no threat to sell its output to another firm if its negotiation with the intended customer fails. Similarly, a final producer cannot threaten to turn to alternative suppliers, if it is not happy with the price it is asked to pay. While our assumption proved useful for keeping the model simple, it is undoubtedly too extreme. In this section, we outline an extension of our model that gives an outside option to both parties to the relationship. After describing the extension, we discuss the determinants of the mode of organization in this more general setting. The details of the analysis are similar to what has come before (albeit more tedious), so we relegate them to an appendix.

Our goal is to extend the model so that input suppliers have an opportunity to sell their components to producers other than those for whom they were intended. When this is true, the suppliers face an important trade-off that is absent from the simple model. On the one hand, an input that is highly specialized will be of maximal value to the prospective customer for whom it is designed. On the other hand, a more standardized and flexible input may be more valuable in alternative uses. The component producer may be able to choose the degree of specificity of its product, trading off value within the intended relationship and value outside. Riordan and Williamson (1985) allowed the degree of specialization to be a choice variable in their analysis of the bilateral hold-up problem. We do likewise here, although in a manner that is rather different from theirs.

To capture input specificity, we associate each final good with a different ideal component. As before, the production of a unit of any final good requires one unit of an intermediate input. If the intermediate is perfect for that variety, then no further inputs are required. However, if the intermediate is not fully specialized to the needs of the final producer, the firm must add labor to make the input fit its purposes. The additional labor costs are greater, the more different is the input from the producer's ideal specification.

Specifically, we adopt a two-dimensional representation of the space of input characteristics.[17] The ideal components for the various final products are arrayed along the circumference of a unit circle, as shown in figure 7. The point labelled i represents

[17] Our discussion in this section applies to a particular industry. We omit the industry subscripts that implicitly are attached to all parameter and variables to make the text easier to read.

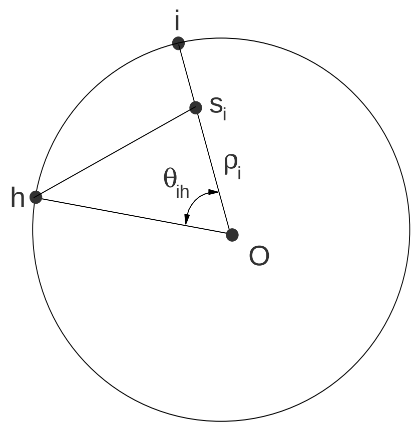

Figure 7: Input characteristics

the characteristics of an intermediate input that is fully specialized to the needs of the producer of final good i. If this producer uses an input with characteristics different from these, it must employ extra resources to make the component "fit." We take the labor requirements per unit of intermediate to be an increasing and convex function of the distance between the intermediate actually used and the product's ideal component. Consider for example the input with characteristics represented by the point s_i in the figure. This input has been designed with the needs of producer i in mind. However, it does not fully meet the producer's specifications. If the firm were to employ this input in producing good i, it would also need to employ labor per unit of output that reflects the distance $\overline{is_i}$. If the producer of product h instead were to use the component with characteristics described by point s_i, its labor costs per unit output would reflect the distance $\overline{hs_i}$ between the intermediate and this other producer's ideal.

For simplicity, we take the labor cost to be proportional to the square of the distance between an input and a producer's ideal, although other functions would do as well. We measure the degree of specialization of an input toward product i by ρ_i, the distance of the input from the center of the circle along the radius leading to point i. The angle θ_{ih} measures the similarity of the ideal components for goods i and h.[18] With these measures, we can write the labor cost to producer i of using the input s_i as $\beta(1-\rho_i)^2$ and the cost to producer h of using the input s_i as $\beta(1+\rho_i^2-2\rho_i\cos\theta_{ih})$, where β reflects the importance of input specificity in the industry under consideration. The input at the center of the circle is a "standardized" or "generic" input; it is not particularly well suited for any of the final producers, but is equally productive in all uses.

The rest of the model is basically as before. Firms in each industry incur fixed costs to enter as vertically integrated or specialized producers. Upon entry, specialized firms search for potential partners. Matching occurs randomly and, as in Section 2, with constant returns to scale. When a supplier and a final producer meet, the latter provides the specifications for its ideal component, as well as technological information needed to produce any intermediate good. A potential input producer that fails to find a partner does not receive this information and has no choice but to exit the industry.[19] Those component producers who find partners choose the quantity, quality, and specification of their products. They may choose to manufacture their inputs precisely to the specifications of their intended customer or to design their inputs more flexibly so that they can readily be sold to other producers.

After the components have been produced, the partners meet to negotiate a sale. It is at this stage that the outside options can make a difference. If a supplier rejects a buyer's offer, it has the possibility of searching for another customer. Similarly, if the buyer refuses the supplier's demands, it might turn elsewhere for its components. However, a flexible technology is not enough to make for a secondary market. There must also be some sellers who are looking for buyers, and *vice versa*, at this later stage. Otherwise, a failed negotiation will leave each party searching in vain for a new partner.

To ensure the existence of a secondary market, we assume that a fraction δ of relationships dissolve exogenously. When a break down occurs, the input producer has no choice but to seek out a new customer for its (already produced) components,

[18] We take the smaller angle between i and h, so that $\theta_{ih} \leq \pi$.

[19] Alternatively, we could assume that unmatched input producers can manufacture certain types of components (e.g., standardized inputs) without guidance from final producers. Then entrants who fail to find a partner in the first round might produce some components in the hope of finding a customer later. This case is a bit more complicated, but not essentially different.

while the final producer must locate a new supplier. The remaining negotiations take place against the backdrop of these exogenous separations. That is, when a component producer and final producer engage in bargaining, the threat for each is to leave the partnership and enter the secondary market where those who have been separated are searching for matches. We take δ to be very small.[20] Still, the fact that it is not zero makes a difference, for it gives each of the firms in every partnership an outside option that otherwise would be lacking.

Matching in the second stage is random, much like in the first. Firms with components to sell have an equal chance of meeting any of the final producers that are seeking inputs, and similarly, each final producer might be matched with any of the input firms. At this stage, there are the same number of input providers searching for customers as there are final producers searching for suppliers. Thus, each firm in the secondary market finds a new partner with probability $\tilde{\eta} \equiv \eta(1)$. In principle, there might be further separations and further rounds of matching after the second, but for simplicity we take the outside options after the second stage to be nil.

We now describe an equilibrium with pervasive outsourcing; details of the analysis can be found in Appendix 2. As before, specialized intermediate and final-good producers enter in numbers that ensure zero expected profits for both types of firms. The input suppliers produce a smaller quantity of components than that which maximizes the joint profits of the two partners; this is a consequence of the imperfect contracting. The new element here is the endogenous degree of specialization. An input provider chooses ρ_i to maximize expected profits. On the one hand, an increase in the degree of specialization enhances potential profits from sales of final good i. Since the component producer shares in these profits, it has an incentive to specialize the good for its partner's use. On the other hand, an increase in ρ_i (beyond a point) reduces the potential value of the input in the secondary market. The component producer seeks to avoid such reductions in outside value, because they weaken its bargaining position vis-à-vis its partner. In choosing the degree of specificity, the supplier strikes a balance between these two opposing forces.

In a symmetric equilibrium, all firms in an industry specialize their inputs to the same extent. And all inputs are sold to the customers for whom they were designed,

[20] Technically speaking, we derive the limit equilibrium as δ approaches zero.

except for the small fraction δ of relationships that break up exogenously. We find that, in equilibrium,

$$\rho^O = \frac{1}{1 + (1 - \omega)\,\tilde{\eta}} \; .$$

The greater is $\tilde{\eta}$, the better is the prospect for a component producer to find a new customer, should the negotiation with its initial partner fail. This means that there is a greater return to producing an input that the average final producer finds attractive. The greater is ω, the greater is the share of the surplus captured by the intermediate producer, and the less the outside option figures in its expected profits. Therefore, a component producer with greater bargaining power produces a more specialized input.

Notice that β does not enter into the determination of the equilibrium degree of specialization. It might seem that component producers will have more of an incentive to specialize their inputs, the more sensitive are manufacturing costs to the degree of specialization. But there are offsetting forces at work here. It is true that the greater is β, the greater is the marginal benefit of specializing the input for the intended user. However, a higher value of β also means that the marginal cost of specialization will be higher, because a more specialized product is less valuable in outside uses when β is large. An increase in per unit adjustment costs has the same proportionate effect on the supplier's outside option as it has on the firm's stake in profits inside the relationship. Thus, there is no effect of β on its choice of design.

We can also examine the determinants of the equilibrium mode of organization. As in the discussion of Section 3, a given industry is quite likely to be characterized either by pervasive integration or by pervasive outsourcing. Most of the parameters have a similar effect on A_I/A_O in the extended model as they do in the simple model. But an interesting new question arises concerning the relationship between the importance of input specificity in an industry and the viability of outsourcing as an organizational form.

The adjustment cost parameter affects the demand level required for specialized firms to break even in three ways. First, the greater is β, the greater is marginal cost for a specialized producer, and so the smaller are the revenues in which the component producers share. Second, the greater is β, the smaller is r_O, because final producers bear the adjustment costs and so enter in relatively small numbers when the costs of imperfect specialization are especially large. A small r_O makes it more difficult for a typical component producer to find a partner. Both of these effects point to a positive association between β and A_O. But also, the greater is β, the smaller is the output of intermediate goods. Since component producers choose their outputs to maximize profits, there is no first-order effect of a change in x_i on the producer's earnings. But when all component producers reduce their output together, collectively they damage the outside option for final producers. This improves the bargaining position of the component producers and, all else equal, enhances their profitability. Although it might seem that outsourcing would be less viable when input specialization is more important, in fact outsourcing may be the unique stable outcome in an industry with a moderately large β where specialized producers could not survive in an otherwise similar industry in which the specificity of the component is less important.

7 Conclusions

This paper incorporates familiar ideas from organization theory into a setting of industry and general equilibrium. We have modeled the "make or buy" decision as a trade-off between diseconomies of scope and the transaction costs that stem from search frictions and incomplete contracts. Our contribution has been to cast the choice of organizational form in an environment where a firm's market opportunities depend on the entry and organizational decisions of others.

Our model allows us to pose questions that could not be addressed in the literature that focuses on bilateral relationships. For example, we examined how the intensity of competition in an industry affects the viability of outsourcing. We found that, where the cost advantage of specialized component producers is large and their bargaining power vis-à-vis specialized final producers is great, outsourcing is more likely to emerge in a stable equilibrium the greater is the substitutability between varieties of final goods. In contrast, when the manufacturing cost advantage of specialized components is modest and the bargaining power of these producers is slight, intense competition between final producers favors vertically-integrated firms. In such industries, outsourcing may require a very low degree of product differentiation, or perhaps an intermediate degree of differentiation.

We also examined how the sensitivity of manufacturing costs to the detailed characteristics of the inputs affects the prospects for outsourcing. With imperfect contracts, specialized input producers face a trade-off between tailoring their output to the needs of a specific customer and preserving the value of inputs in alternative uses. By specializing the inputs, the suppliers maximize the profits in which they share, but compromise their bargaining power. In equilibrium, the inputs that can be acquired via outsourcing are partially specialized for their intended uses. Surprisingly, the extent of specialization does not depend on the sensitivity of final-producers' costs to input characteristics. Also, since vertically integrated firms produce the ideal component for their own purposes, the cost advantage of specialized production shrinks as input specificity becomes more important. Still, outsourcing may be viable in an industry when costs are moderately sensitive to input characteristics, but not viable when they are only slightly so. Our findings reflect the importance of the outside options for the various producers, which cannot be considered except in an equilibrium analysis.

The main contribution of this paper has been to provide a simple general equilibrium framework for studying the equilibrium mode of organization, the resulting degree of input specialization, and other variables of interest, such as prices and variety choice. Our model is simple enough to allow modifications and extensions, for example to a richer menu of contractual options, to different matching technologies and to alternative types of corporate partnerships. We believe that it can be used to shed light on important issues, such as the increasing extent of specialization and especially the causes and consequences of the rapid growth of international outsourcing.

References

[1] Abraham, Katharine G. and Taylor, Susan K. (1996), "Firm's Use of Outside Contractors: Theory and Evidence," *Journal of Labor Economics, 14*, 394-424.

[2] Aghion, Philippe, Dewatripont, Mathias and Rey, Patrick (1994), "Renegotiation Design with Unverifiable Information," *Econometrica, 62,* 257-282.

[3] Audet, Denis (1996), "Globalization in the Clothing Industry," in *Globalization of Industry: Overview and Sector Reports*, Paris: Organization for Economic Cooperation and Development.

[4] Blanchard, Olivier J. and Diamond, Peter A. (1989), "The Beveridge Curve," *Brookings Papers on Economic Activity*, 1, 1-60.

[5] Campa, José and Goldberg, Linda (1997), "The Evolving External Orientation of Manufacturing Industries: Evidence from Four Countries," NBER Working Paper No. 5958, Cambridge MA.

[6] Chinitz, Benjamin (1961), "Contrasts in Agglomeration: New York and Pittsburgh," *American Economic Review* (Papers and Proceedings), 51, 279-289.

[7] Coase, Ronald H. (1937), "The Nature of the Firm," *Economica, 4*, 386-405.

[8] Coles, Melvin G. and Smith, Eric (1996), "Cross-Section Estimation of the Matching Function: Evidence from England and Wales," *Economica*, 63, 589-597.

[9] Diamond, Peter A. (1982), "Wage Determination and Efficiency in Search Equilibrium," *Review of Economic Studies*, XLIX, 217-227.

[10] Dixit, Avinash K. and Stiglitz, Joseph E. (1977), "Monopolistic Competition and Optimum Product Diversity," *American Economic Review, 67*, 297-308.

[11] Ford, I. David, Cotton, G. Barry, Gross, Andrew, and Wilkinson, Ian (1993), "Make-or-Buy Decisions and Their Implications," *Industrial Marketing Management, 22*, 207-214.

[12] Grossman, Sanford J. and Hart, Oliver (1986), "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration," *Journal of Political Economy, 94*, 691-719.

[13] Hart, Oliver (1995), *Firms, Contracts, and Financial Structure*, Oxford: Oxford University Press.

[14] Hart, Oliver and Moore, John (1990), "Property Rights and the Nature of the Firm," *Journal of Political Economy, 98,* 1119-1158.

[15] Hart, Oliver and Moore, John (1999), "Foundations of Incomplete Contracts," *Review of Economic Studies, 66*, 115-138.

[16] Helper, Susan (1991), "Strategy and Irreversibility in Supplier Relations: The Case of the U.S. Automobile Industry," *Business History Review, 65*, 781-824.

[17] Hummels, David, Rapoport, Dana and Yi, Kei-Mu (1998), "Vertical Specialization and the Changing Nature of World Trade," *Federal Reserve Bank of New York Economic Policy Review, 4,* 79-99.

[18] Klein, Benjamin, Crawford, Robert G. and Alchian, Armen A. (1978), "Vertical Integration, Appropriable Rents, and the Competitive Contracting Process," *Journal of Law and Economics*, 21, 297-326.

[19] Lagos, Ricardo (2000), "An Alternative Approach to Search Frictions," *Journal of Political Economy*, 108, 851-873.

[20] Maskin, Eric and Tirole, Jean (1999), "Unforeseen Contingencies and Incomplete Contracts," *Review of Economic Studies, 66*, 83-114.

[21] McAfee, R. Preston and McMillan, John (1995), "Organizational Diseconomies of Scale," *Journal of Economics and Management Strategy*, 4, 399-426.

[22] McMillan, John (1995), "Reorganizing Vertical Supply Relationships," in H. Siebert, ed., *Trends in Business Organization: Do Participation and Cooperation Increase Competitiveness*, Tübingen: J.C.B. Mohr, 203-222.

[23] Perry, Martin K. (1989), "Vertical Integration: Determinants and Effects," in R. Schmalansee and R.D. Willig, eds., Handbook of Industrial Organization, Amsterdam: North Holland, 185-255.

[24] Pissarides, Christopher A. (2000), *Equilibrium Unemployment Theory, Second Edition*, Cambridge: MIT Press.

[25] Riordan, Michael H. and Williamson, Oliver E. (1985), Asset Specificity and Economic Organization," *International Journal of Industrial Organization*, 3, 365-378.

[26] McLaren, John (2000), "'Globalization' and Vertical Structure," *American Economic Review*, 90, 1239-1254.

[27] Segal, Ilya (1999), "Complexity and Renegotiation: A Foundation for Incomplete Contracts," *Review of Economic Studies, 66*, 57-82.

[28] Williamson, Oliver E. (1975), *Markets and Hierarchies: Analysis and Antitrust Implications*, New York: Free Press.

[29] Williamson, Oliver E. (1985), *The Economic Institutions of Capitalism*, New York: Free Press.

[30] Yeats, Alexander J. (1998), "Just How Big is Global Production Sharing?" Policy Research Working Paper No. 1871, The World Bank Development Research Group.

Appendix 1

8 Stability

In our discussion of stability in the text, we constrained specialized producers to enter in the unique ratio that is consistent with zero expected profits for both types of firms. There is of course no mechanism that ensures coordinated entry of this sort. We show in this appendix that the intuition developed in the two-dimensional stability analysis is borne out by a more complete analysis of the three dimensional dynamical system.

Consider an adjustment process in which firms of a given type enter the market if their expected profits are positive, and exit if expected profits are negative. More specifically, suppose that

$$\dot{s} = \gamma_s \pi_s,$$

$$\dot{m} = \gamma_m \pi_m$$

$$\dot{v} = \gamma_v \pi_v$$

where γ_i is a positive constant for $i = s, m, v$. Of course, there cannot be a negative number of any type of firm, so we assume that $\dot{s} = 0$ when $s = 0$ and $\pi_s < 0$, and similarly for the other producer types.

Using (9) and (10), we find $\pi_v = 0$ when

$$\frac{(1-\alpha)\,\mu L \left(\frac{\lambda}{\alpha}\right)^{-\frac{\alpha}{1-\alpha}}}{v\left(\frac{\lambda}{\alpha}\right)^{-\frac{\alpha}{1-\alpha}} + n\,(s,m)\left(\frac{1}{\omega\alpha}\right)^{-\frac{\alpha}{1-\alpha}}} = k_v.$$

Using (13), this condition can be rewritten as

$$v\left(\frac{\alpha}{\lambda}\right)^{\frac{\alpha}{1-\alpha}} + n\,(s,m)\,(\alpha\omega)^{\frac{\alpha}{1-\alpha}} = \frac{\mu L}{A_I}. \qquad (21)$$

Equation (21) gives combinations of v, s and m at which the operating profits for a typical vertically integrated producer are equal to its fixed cost. The equation describes a downward sloping surface $\mathcal{V}$ in (s, m, v) space, as depicted in figure 8.

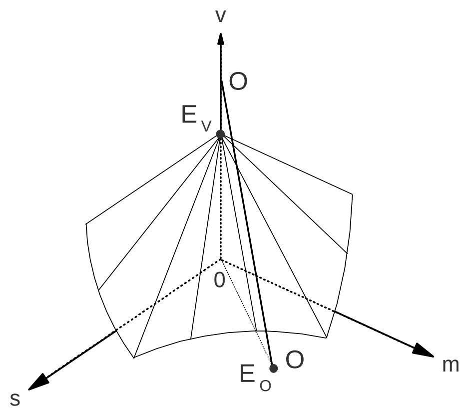

Figure 8: Three dimensional dynamics

Above the surface, $\pi_v < 0$ and so v declines. Below the surface, $\pi_v > 0$ and v increases. Intuitively, an increase in the number of any type of firm implies an increase in the number of industry varieties, which reduces the demand for a given product. The figure also shows contours on the surface of $\mathcal{V}$ along which the ratio m/s is constant. These are depicted by straight lines.

Next, we find the points at which $\dot{s} = 0$ and $\dot{m} = 0$. The boundaries of these sets are represented by the combinations of s, m and v that ensure $\pi_s = 0$ and $\pi_m = 0$, respectively. Using (5), (6) and (10), these boundaries are given by

$$\frac{n(s,m)}{s} \frac{\mu L \left(\frac{1}{\omega\alpha}\right)^{-\frac{\alpha}{1-\alpha}}}{v\left(\frac{\lambda}{\alpha}\right)^{-\frac{\alpha}{1-\alpha}} + n(s,m)\left(\frac{1}{\omega\alpha}\right)^{-\frac{\alpha}{1-\alpha}}} = k_s, \tag{22}$$

$$\frac{n(s,m)}{m} \frac{(1-\alpha)\mu L \left(\frac{1}{\omega\alpha}\right)^{-\frac{\alpha}{1-\alpha}}}{v\left(\frac{\lambda}{\alpha}\right)^{-\frac{\alpha}{1-\alpha}} + n(s,m)\left(\frac{1}{\omega\alpha}\right)^{-\frac{\alpha}{1-\alpha}}} = k_m. \tag{23}$$

Figure 9 shows three pairs of curves in (s, m) space. Curve S_2S_2 depicts the combinations of s and m that imply $\pi_s = 0$ when $v = v_2$. Curve M_2M_2 shows combinations of s and m that imply $\pi_m = 0$, when $v = v_2$. These curves intersect at point Q_2, which is on the ray defined by equation (11) and shown as a broken line in the figure. Similarly, S_1S_1 and M_1M_1 depict the rest points for s and m, respectively, when $v = v_1$. The intersection point, Q_1, also falls on the ray defined by (11). In

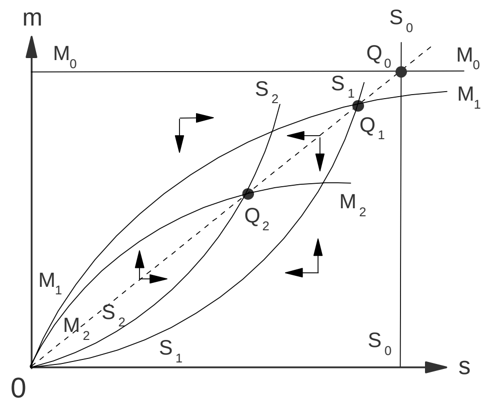

Figure 9: Entry of specialized producers

the limit, as v approaches zero, the corresponding SS curve becomes vertical while the corresponding MM curve becomes horizontal. The curves along which $\pi_s = 0$ and $\pi_m = 0$ when $v = 0$ are depicted by the horizontal and vertical lines, S_0S_0 and M_0M_0, respectively. Point Q_0 represents the number of firms in an equilibrium with pervasive outsourcing.

Suppose that $v = v_2$ at some moment in time. Specialized producers of final goods face positive expected profits to the left of S_2S_2, and so these are points at which s is growing. Expected profits for final producers are negative to the right of the curve, so here s is shrinking. The arrows indicate the evolution in the number of this type of firm. Similarly, specialized component producers anticipate positive expected profits below M_2M_2 and negative expected profits above this curve. Again, the arrows show the evolution in the number of these firms. In all, the entry and exit of specialized producers induces an initial movement of the system in the direction of point Q_2. However, the number of integrated producers v is changing at the same time: if v_2 is below the surface $\mathcal{V}$ in figure 8, then v is growing, and the SS and MM curves shift inward; if v_2 is above the surface $\mathcal{V}$ then v is shrinking, and the SS and MM curves shift outward.

Let $\mathcal{Q}$ denote the set of all non-negative values of (s, m, v) that solve equations (22) and (23). Using (12), this set can also be characterized by the values of (s, m, v)

that solve (11) and

$$v\left(\frac{\alpha}{\lambda}\right)^{\frac{\alpha}{1-\alpha}}+n\left(s,m\right)\left(\omega\alpha\right)^{\frac{\alpha}{1-\alpha}}=\frac{\mu L}{A_O}. \tag{24}$$

The set $\mathcal{Q}$ defines a line in (s,m,v) space, which is represented by OO in figure 8.[21] Along this line, both types of specialized firms have zero expected profits. When $A_O < A_I$, the line OO lies everywhere above the surface $\mathcal{V}$; when $A_O > A_I$, it lies everywhere below the surface. This is because, by definition, at each point in $\mathcal{Q}$ the industry demand level is A_O, whereas at each point on $\mathcal{V}$ the industry demand is A_I.

Figure 8 depicts a case where the surface $\mathcal{V}$ is below the line OO. Thus, $A_O < A_I$ for all points on $\mathcal{V}$. Point E_V represents an industry equilibrium in which all firms are vertically integrated. Point E_O represents another industry equilibrium in which outsourcing is pervasive. We now consider the stability of each of these equilibrium points.

Consider first the equilibrium at point E_V. If the number of firms is perturbed to a point below the surface $\mathcal{V}$, then v will be rising while entry of specialized producers will cause the system to evolve toward the line OO. This process must continue until the point representing the state of the system crosses the surface $\mathcal{V}$, at which time v will start to decline. While v declines, s and m continue to evolve towards OO. Thus, the surface $\mathcal{V}$ will never be crossed again. In this case, the system converges to E_O. If, instead, the equilibrium at E_V is perturbed initially to a point above the surface $\mathcal{V}$, the number of vertically integrated firms converges monotonically to zero, while s and m evolve until the line OO is reached. Again, the system converges to E_O.

Different dynamics occur when $A_O > A_I$. Then the line OO lies everywhere below the $\mathcal{V}$ surface. In such a case (not illustrated in the figure) there is no equilibrium with pervasive outsourcing. No matter what the initial conditions, the system converges to a point such as E_V, where $\mathcal{V}$ intersects the v axis. Thus, there is a unique stable equilibrium in which all entrants are vertically integrated.

Finally, in the limiting case in which $A_O = A_I$, line OO is located on the surface $\mathcal{V}$. Then there is a continuum of equilibrium points. The initial conditions determine

[21] Note that this is strictly true only up to an upper limit on v, at which the equilibrium point Q in figure 9 converges to the origin. This limiting value for v is the one at which line OO in figure 8 meets the v axis.

the final resting point and the numbers of each type of firm associated with the mixed equilibrium.

Appendix 2

9 A Model of Partial Specialization

In this appendix, we analyze the model with partial specialization of intermediate goods and discuss how the sensitivity of manufacturing costs to input specifications affects the viability of outsourcing as an equilibrium mode of organization. We focus on an industry j, and omit the subscripts on the industry-specific variables.

9.1 Profitability

The prospect of a secondary market in partially specialized components has no bearing on the decisions of a vertically integrated firm. Given an industry demand level A, such a firm maximizes profits by choosing to fully specialize its inputs, by pricing according to (7), and by selling output according to (8). Thus, (9) gives the maximal operating profits for a vertically integrated firm. The typical such firm covers the fixed costs of entry and operation if and only if the industry demand level exceeds A_I, where A_I is given by (13).

We now describe the profitability of specialized suppliers. It is convenient to begin with the secondary market. Consider a second-stage match between the specialized producer of variety h and a specialized supplier of intermediates with a quantity x_i of an input specialized to degree ρ_i to the needs of the producer of good i. If a sale takes place, the final producer can produce output to meet the demand (2). The per unit cost of that output is $\phi(\rho_i, \theta_{ih})$ for $y_h \leq x_i$, where $\phi(\rho_i, \theta_{ih}) \equiv \beta(1 + \rho_i^2 - 2\rho_i \cos \theta_{ih})$ reflects the cost of tailoring the inputs to the needs of this particular producer. The quantity x_i serves as a bound on the possible output of final good h.

Let $\Pi(\rho_i, x_i, \theta_{ih})$ represent the resulting profits; i.e., the revenues less the cost of retrofitting the inputs. Figure 10 depicts the determination of $\Pi(\cdot)$. As usual, profit maximization entails a comparison of marginal revenue and marginal cost. The marginal revenue curve slopes downward; its location depends on the equilibrium value of the industry demand parameter A. Marginal cost is constant at $\phi(\rho_i, \theta_{ih})$ for $y_h \leq x_i$, and becomes infinite at x_i. The figure depicts the case where it is optimal for

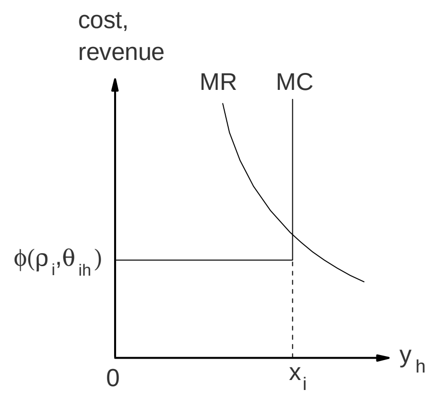

Figure 10: Choice of output in second-round match

the final producer to use the entire stock of available inputs. Alternatively, it may be optimal for the firm to discard some of the components, if they are not particularly well suited for the production of good h (in which case, marginal cost is high). In any case, $\Pi(\rho_i, x_i, \theta_{ih})$ represents the surplus that the partners can share if they meet in the secondary market. With bargaining, the input provider can expect to capture a fraction ω of this surplus, while the final-good producer can expect to capture the remaining fraction $1-\omega$.

Now we can calculate the "outside options" available to firms of each type in the first round. If a final producer fails to strike a deal with its first-round partner, it will enter the secondary market. Since there will be an equal number of intermediate producers and final producers searching in the secondary market, the firm can expect to find a new partner with probability $\tilde{\eta} = \eta(1)$. The firm faces further uncertainty about the identity of a potential second-round supplier, if it is successful in finding one. It may find a supplier with components to sell that approximately fit its needs, or it may find one with components that are rather unsuitable. The outside option for the final producer, denoted $O_s(\rho, x)$, is the probability of finding a new partner times the expected value of its share in the resulting second-round profits, or

$$O_s(\rho, x) = \tilde{\eta}(1-\omega)\frac{1}{\pi}\int_0^{\pi} \Pi(\rho, x, \theta)d\theta. \tag{25}$$

Notice that the expectation is taken over all of the possible values of θ, measuring the fit between a potential second-round supplier and the final producer in question. We have omitted the subscripts i, because we seek a symmetric equilibrium in which all components are specialized to the same extent and the same quantity is produced of each one.

Similarly, an input producer who fails to come to terms with an initial partner can expect to find a second-round match with probability $\tilde{\eta}$. If it is successful, it faces further uncertainty about the quality of that match. If the firm meets a final producer with needs close to what it has to offer, the second-round surplus will be large. Otherwise, it may be small. The expected proceeds for an input producer that enters the secondary market in search of a new partner are

$$O_m(\rho_i, x_i) = \tilde{\eta}\omega\frac{1}{\pi}\int_0^{\pi}\Pi(\rho_i, x_i, \theta)d\theta. \tag{26}$$

We leave the subscripts i in (26) to remind ourselves that the outside option depends on the prior choices made by this particular input producer.

Now consider the first-round negotiation between an input supplier and its initial partner. Let the partner be the producer of final good i. The final producer stands to reap revenues of $p\,(x_i; A)\,x_i$ if the input supplier produces a quantity x_i of high-quality inputs and if all these inputs are used to produce final output; i.e., $y_i = x_i$, where $p\,(x_i; A) = (A/x_i)^{1-\alpha}$ is the inverse of (2).[22] The variable cost of the final output will be $\beta(1-\rho_i)^2 x_i$ if the input is specialized to degree ρ_i. If the first-round match does not dissolve exogenously, the partners will share in the surplus from the relationship, which is the difference between variable profits and the sum of the outside options of the two firms. The bargaining weights are ω for the input provider and $1-\omega$ for the final producer, as before. Exogenous separations occur with probability δ. Since we take δ close to zero, the input producer can expect gross earnings of

$$O_m(\rho_i, x_i) + \omega\left[p\,(x_i; A)\,x_i - \beta(1-\rho_i)^2 x_i - O_s(\rho, x) - O_m(\rho_i, x_i)\right]$$

if it produces x_i units of the component and specializes it to degree ρ_i. This is the sum of the firm's outside option plus a fraction ω of the surplus in its relationship with the producer of final good i.[23]

[22] The input producer would never manufacture more inputs than its first-round customer would use, because doing so adds cost without introducing the possibility of extra revenues at a later stage.

[23] In this equation, ρ and x represent the identical choices made by all other input producers in the symmetric equilibrium.

The input producer chooses ρ_i and x_i to maximize its expected earnings net of manufacturing costs. Therefore, it solves

$$\max_{\rho_i, x_i} \omega \left[p\left(x_i; A\right) x_i - \beta(1-\rho_i)^2 x_i - O_s(\rho, x) \right] + (1-\omega) O_m(\rho_i, x_i) - x_i. \tag{27}$$

The choice of specificity reflects a trade-off between the value of the components inside the relationship and their value in the secondary market. A higher value on the outside (higher O_m) means more bargaining power for the supplier when it negotiates with the final producer. The choice of quantity reflects a balancing of the marginal addition to the supplier's gross earnings and the (full) manufacturing cost.

We proceed now to characterize these choices. In order to avoid a taxonomy, we limit our attention to cases in which the cost of retrofitting components is not too large. In particular we adopt

Parameter Restriction 1: $\beta \leq \frac{1+(1-\omega)\tilde{\eta}}{2\omega[2+(1-\omega)\tilde{\eta}]}$.

Recall from figure 10 that a final-good producer may or may not use all of the components available from a second-round supplier, depending on the scale of market demand and the height of marginal cost. The parameter restriction will ensure that all components are in fact used, no matter how poor the second-round match happens to be.

Suppose it is optimal to use all components in any second-round match. Then, $\Pi(\rho_i, x_i, \theta_{ih}) = p\left(x_i; A\right) x_i - \beta x_i(1 + \rho_i^2 - 2\rho_i \cos\theta_{ih})$, the difference between revenues from the sale of $y_h = x_i$ units of the final good h and the cost to the final producer of using the less-than-ideal components. The outside option $O_m(\rho_i, x_i)$ is a fraction $\tilde{\eta}\omega$ of the expected profit across all possible second-round matches. Therefore,

$$\begin{aligned} O_m(\rho_i, x_i) &= \omega\tilde{\eta}\frac{1}{\pi}\int_0^{\pi} \left[p\left(x_i; A\right) x_i - \beta x_i \left(1 + \rho_i^2 - 2\rho_i \cos\theta\right) \right] d\theta \\ &= \omega\tilde{\eta} \left[p\left(x_i; A\right) x_i - \beta x_i \left(1 + \rho_i^2\right) \right]. \end{aligned}$$

The solution to (27) yields[24]

$$\rho_s = \frac{1}{1+(1-\omega)\tilde{\eta}}, \tag{28}$$

$$p_s = \frac{\rho_s}{\alpha\omega}\left[1+\beta\omega(1-\omega)\tilde{\eta}(1+\rho_s)\right] \tag{29}$$

and

$$y_s = x_s = A\left\{\frac{\alpha\omega}{\rho_s\left[1+\beta\omega(1-\omega)\tilde{\eta}(1+\rho_s)\right]}\right\}^{\frac{1}{1-\alpha}} \tag{30}$$

in a symmetric equilibrium.

Notice that $\rho_s < 1$. Evidently, input producers specialize their components only partially. This represents another disadvantage of outsourcing relative to vertical integration. We have discussed in the text the determinants of ρ_s; in particular, that specialization increases with the bargaining weight for input providers and decreases in the probability of matching when there are equal numbers of firms on each side of the market. We also noted that ρ_s is independent of the value of β in the industry.

Expected profits for specialized producers of final goods and intermediate goods are

$$\pi_s = \eta(r)\,R_s(\rho_s, x_s) - k_s,$$

and

$$\pi_m = \frac{\eta(r)}{r}R_m(\rho_m, x_m) - k_m,$$

respectively, where

$$R_s(\rho_s, x_s) = O_s(\rho_s, x_s) + (1-\omega)\left[p_s x_s - \beta x_s(1-\rho_s)^2 - O_s(\rho_s, x_s) - O_m(\rho_s, x_s)\right]$$

are expected operating profits of a firm that enters as a specialized producer of final goods and

$$R_m(\rho_m, x_m) = O_m(\rho_s, x_s) + \omega\left[p_s x_s - \beta x_s(1-\rho_s)^2 - O_s(\rho_s, x_s) - O_m(\rho_s, x_s)\right] - x_s$$

[24] We can now check the conditions under which all available inputs will be used in a second-round match. With the demand function in (2), marginal revenue equals $\alpha p = \rho_s\left[1+\beta\omega(1-\omega)\tilde{\eta}(1+\rho_s)\right]/\omega$. The worst possible second-round match has $\theta = \pi$, and therefore $\phi = \beta(1+\rho_s)^2$. But $\beta \le [1+(1-\omega)\tilde{\eta}]/2\omega[2+(1-\omega)\tilde{\eta}]$ ensures $\rho_s\left[1+\beta\omega(1-\omega)\tilde{\eta}(1+\rho_s)\right]/\omega \ge \beta(1+\rho_s)^2$ when $\rho_s = 1/[1+(1-\omega)\tilde{\eta}]$.

are the expected operating profits of one that enters as a specialized producer of intermediates. Recall that $r = m/s$ is the ratio of the numbers of these two types of entrants.

From (25), (26) and (28)-(30), we can compute the values of r and A that are needed for both types of specialized entrants to have zero expected profits. Denoting these values by $\hat{r}_O$ and $\hat{A}_O$, respectively, we find that

$$\hat{r}_O = \frac{\omega\left[p_s - \beta(1-\rho_s)^2\right] - 1}{(1-\omega)\left[p_s - \beta(1-\rho_s)^2\right]} \frac{k_s}{k_m}, \tag{31}$$

and

$$\hat{A}_O = \frac{k_m\left(p_s\right)^{\frac{1}{1-\alpha}}}{\omega\left[p_s - \beta(1-\rho_s)^2\right] - 1} \frac{\hat{r}_O}{\eta\left(\hat{r}_O\right)}. \tag{32}$$

where ρ_s and p_s are given in (28) and (29). These values can now be used to examine the equilibrium modes of organization.

9.2 Equilibrium Organization

As in the simple model, all industry equilibria are characterized either by pervasive vertical integration or by pervasive outsourcing, except in a knife-edge case. An industry equilibrium with entry by both integrated and specialized producers would require all types of firms to break even. But this can happen only if $A_I = \hat{A}_O$, which in turn requires a particular configuration of parameter values. As before, we can compare A_I and $\hat{A}_O$ to understand the factors that favor one form of industrial organization over the other.

The results of such a comparison are much like those for the simple model, so we will not repeat them here. Our discussion focuses instead on the new parameter β. Recall that this parameter measures the sensitivity of manufacturing costs to the specificity of the intermediate good. All vertically-integrated producers fully specialize their inputs, so β does not affect A_I. Therefore, we can study how input specificity affects the mode of organization by examining the effect of changes in β on the demand level $\hat{A}_O$ needed for the viability of specialized firms.

It might seem that, as costs become more sensitive to input characteristics, a higher level of demand will be needed for specialized firms to break even . However, we find that an increase in β may increase or decrease $\hat{A}_O$, depending upon the other parameter values. To understand why this is so, we must think about how changing β affects the profitability of specialized firms, both through earnings $R_s(\cdot)$ and $R_m(\cdot)$, and through the probabilities of finding partners. There is a direct effect on earnings of the increase in manufacturing costs and an indirect effect that reflects the induced change in the output of intermediates. The direct effect reduces joint profits, given output, and both intermediate and final producers share in this loss. As for the indirect effect, we observe from (30) that $dx/d\beta = dy/d\beta < 0$. An increase in the cost of retrofitting the inputs reduces the incentive that input providers have to produce intermediates. Since the equilibrium output is smaller than the amount that maximizes revenues less adjustment costs, the indirect effect harms final producers as well. But the decline in output benefits the intermediate producers. These producers choose their own x_i to maximize profits, taking the outputs of their rivals as given. By the envelope theorem, a change in x_i would have no first-order effect on a firm's profits, if others' output levels were to remain fixed. But the marginal output of each input producer generates a negative externality for the others, by improving the outside option for final-good producers. When all input producers reduce their outputs together, the marginal effect on their joint profits (for given β) is positive. Moreover, Parameter Restriction 1 ensures that the indirect effect of the fall in output is stronger than the direct effect of the rise in costs. Thus, these two factors together tend to reduce the level of industry demand necessary for input providers to break even.

An increase in β also changes the ratio in which specialized intermediate and final good producers enter the market. Since the profitability of intermediate producers rises, while that of final producers falls, the ratio $\hat{r}_O = \hat{s}_O/\hat{m}_O$ must decline. This reduces the probability that a given input provider will find a match. Holding all else constant, $\hat{A}_O$ grows when finding a partner becomes more difficult for the input providers.

Taking the three effects together, there is no guarantee that $\hat{A}_O$ will rise as the sensitivity of manufacturing costs to input specifications grows. For example, suppose that $\omega = 0.5$, $\tilde{\eta} = 1, \alpha = 0.5$ and $\varepsilon_\eta = 0.5$. Then $\hat{A}_O$ declines with β for small values of β and rises with β when β is large. This means that outsourcing will be viable in industries in which manufacturing costs are moderately sensitive to input specifications, but not in otherwise similar industries in which the sensitivity is either very small or very large.