4 Outsourcing, Contracts, and Innovation Networks

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4.1 Introduction

A substantial growth in the outsourcing of activities in industrial countries is the most recent form of a greater division of labor (Feenstra 1998). When corporations began selling their factories and relocating manufacturing in the 1980s and 1990s to boost efficiency and focus on specialization, most insisted that important R&D would remain in-house. Today leading multinationals are turning toward a new approach to innovation, one that employs global networks of partners.

Dell, Hewlett-Packard, Motorola, and Philips, among others, have started buying complete designs of some digital devices from Asian developers, modifying them to their own specifications, and using their own brand names. Dell, for example, does little of its own design for notebook PCs, digital TVs, or other products. Hewlett-Packard contributes key technology and some design to all its products but relies on outside partners to codevelop everything from servers to printers. Motorola buys complete designs for its cheapest phones but controls all of the development of high-end handsets. Asian contract manufacturers and independent design houses have become key players in nearly every technological device, from laptops and high-definition TVs to MP3 music players and digital cameras. While the electronics sector is the most significant example of search for offshore help with innovation, the concept is spreading to nearly every sector of the economy. Boeing, for instance, is working with India's HCL Technologies to codevelop software for everything from navigation systems and landing gear to the cockpit controls. Pharmaceuticals as GlaxoSmithKline and Eli Lilly are teaming up with Asian biotech research companies in a bid to cut the average $500 million cost of bringing a new drug to market. Procter & Gamble also wants half of its new product ideas to be generated from outside by 2010, compared with 20 percent now (Engardio and Einhorn 2005).

The growing importance of outsourcing has generated an intense debate on the costs and benefits of industrial fragmentation. Within the international trade literature, a recent strand of research tries to investigate the phenomenon of outsourcing as the result of a trade-off between the governance costs of complex vertical organizations and the contractual costs of networks of independent specialized upstream and downstream producers. Such networks are tainted by problems of contractual incompleteness stemming from the lack of ex post verifiability by third parties as the quality of deliverables is too costly to observe by courts. Related models can be classified in terms of their relative focus on two decisions: the "ownership decision" on whether production should be in-house or outsourced and the "location decision" on where to place production. The ownership decision is the focus of, for example, McLaren (2000) and Grossman and Helpman (2002) for a closed economy and Antras (2003), Grossman and Helpman (2003), and Feenstra and Hanson (2003, 2004) for an open economy. The location decision is analyzed by Grossman and Helpman (2005). Both decisions appear in Antras and Helpman (2004) as determinants of firm organizational form.[1]

While all these studies focus on the static effects of outsourcing, we investigate instead its dynamic effects. Our aim is to shed light on the driving forces behind the new approach to innovation based on global networks of partners. In so doing, we model an industry in which R&D is performed by independent research labs and outsourcing production requires complementary upstream and downstream inventions. In the presence of search friction and incomplete outsourcing contracts, we show that the ex post bargaining power of upstream and downstream parties at the production stage feeds back to R&D incentives, thus affecting the emergence and the performance of networks of labs specialized in complementary inventions.

In our model, R&D is always outsourced, and independent labs choose whether to invent integrated upstream and downstream production processes or to focus on specialized upstream or downstream innovation. Lai, Riezman, and Wang (2005) endogenize the decision to outsource R&D rather than perform it in-house by emphasizing the trade-off between the costs of information leakage and the benefits of specialization. In Acemoglu, Aghion, and Zilibotti (2005), R&D is always performed in-house, and firms closer to the technology frontier have a stronger incentive to outsource production in order to concentrate on more valuable R&D. Our model thus complements both contributions. This is achieved by introducing innovation and growth in the static outsourcing model of Grossman and Helpman (2002), who study the industrial organization of a sector in which the varieties of a horizontally differentiated good are produced by monopolistically competitive firms. Production has two stages: intermediate supply and final assembly. Firms choose whether to enter as intermediate suppliers, final assemblers, or vertically integrated firms by paying the corresponding organization-specific fixed costs. Vertical integration bears additional costs due to more complex governance and limited specialization. Specialized suppliers face, instead, additional costs of searching and contracting with complementary partners. Contracts themselves are incomplete due to input characteristics that are unverifiable by third parties, which leads to bargaining between intermediate suppliers and final assemblers after the former have produced their inputs. In Grossman and Helpman (2002) unobservable intermediate input quality is an issue insofar as only high-quality inputs can be processed, whereas low-quality inputs are useless even though supplied at zero cost.[2] The fear of being held up during the bargaining process causes the intermediate suppliers to underproduce, and this reduces the joint surplus of specialized firms with respect to vertically integrated ones. Accordingly, the choices of firms in terms of organizational modes depend on the balance between the costs of the two types of industrial structure.

Grossman and Helpman (2002) show that the bargaining power of partners plays a key role in the fragmentation of production. Outsourcing is preferred when specialized final assemblers have a good chance of finding specialized intermediate suppliers; when product differentiation is weak so that the profit portion of the revenues of vertically integrated firms is small relative to the share appropriated by final assemblers through bargaining in an outsourcing deal; when vertical revenues are relatively small due to large gains from specialization and mild intermediate underproduction thanks to strong supplier bargaining power; and when the entry costs for specialized assembly are relatively small compared with those for vertically integrated production. The matching probability of firms entering as specialized assemblers itself depends negatively on their relative costs of entry and positively on their relative profit margin with respect to intermediate suppliers. The result is a relationship between the incentives to outsource and supplier bargaining power that has an inverted-U shape. Intuitively, when their bargaining power is very weak, intermediate suppliers have little incentive to produce, so intermediates are very costly. When intermediate bargaining power is very strong, few final assemblers are attracted to the industry, so intermediate suppliers have little chance of finding partners.

To the static setup of Grossman and Helpman (2002) we add dynamic product innovation. Whatever their organizational choice, firms need blueprints for production to enter the market. These are invented by perfectly competitive labs. They are protected by infinitely lived patents and come in three organization-specific types depending on whether they are designed for vertical integration, intermediate supply, or final assembly. We show that for specific parameter values, the steady state of the dynamic model is isomorphic to the static equilibrium of Grossman and Helpman (2002) once their fixed entry costs are interpreted as the marginal costs of innovation.[3] Our analysis therefore complements their work by providing microfounded transitionary dynamics. This has three interesting implications. First, explicit dynamics allow a formal stability analysis and qualify the conditions for the existence of multiple equilibria.[4] Second, they introduce new microeconomic parameters that are shown to affect the steady-state outcomes. Third, they allow characterizing the path and speed of convergence to steady state after the economy is hit by some shock.[5]

Some parameters have the same impact independent of the industrial organization of firms. Weaker product differentiation reduces product development due to thinner profit margins. Also, faster depreciation has a negative impact on product development. Both discourage innovation and divert labor away from the latter. Stronger time preference slows product development by biasing intertemporal decisions toward consumption. Higher costs of innovation have a negative impact on product development, whereas a larger economy supports the creation of a proportionately larger number of product varieties.

The relationship between the incentives to outsource and the bargaining power of intermediate suppliers has the same inverted-U shape as in Grossman and Helpman (2002), and for the same reasons. Accordingly, outsourcing is sustainable in an industry equilibrium only if supplier bargaining power is neither too weak nor too strong. When the outsourcing mode is selected, supplier bargaining power plays a crucial role for innovation. In particular, product development is maximized when supplier bargaining power does not take extreme values.

The rest of the chapter is organized as follows. Section 4.2 presents the model. Section 4.3 determines the equilibrium of the dynamic model. Section 4.4 concludes.

4.2 A Model of Product Innovation

To study the organizational choice between vertical integration and outsourcing in a dynamic environment, we merge the organization model with incomplete contracts by Grossman and Helpman (2002) and the innovation model with horizontal product differentiation by Grossman and Helpman (1991).

4.2.1 Demand

There are L infinitely lived households that share the same preferences defined over the consumption of a horizontally differentiated good C. The utility function is assumed to be instantaneously Cobb-Douglas and intertemporally constant elasticity of substitution (CES) with unit elasticity of intertemporal substitution:

$$U = \int_0^\infty e^{-\rho t} \ln C(t)\, dt,$$

where $\rho > 0$ is the rate of time preference and

$$C(t) = \left[\int_0^{n(t)} c(i,t)^\alpha \, di \right]^{1/\alpha}$$

is a CES quantity index in which $c(i,t)$ is the consumption of variety i, $n(t)$ is the mass ("number") of varieties produced, and α is an inverse measure of the degree of product differentiation between varieties. In particular, if σ is defined as the constant own- and cross-price elasticity of demand, then $\alpha = 1 - 1/\sigma$. Households have perfect foresight, and they can borrow and lend freely in a perfect capital market at instantaneous interest rate $R(t)$.

Given the chosen functional forms, multistage budgeting can be used to solve the utility maximization problem. This allows the households' decisions to be modeled as a two-stage sequence. In the first stage, they allocate their income flow in each period between savings and expenditures. This yields a time path of total expenditures $E(t)$ that obeys the Euler equation of a standard Ramsey problem:

$$\frac{\dot{E}(t)}{E(t)} = R(t) - \rho, \tag{4.1}$$

where we have used the fact that the intertemporal elasticity of substitution equals unity. By definition, $E(t) = P(t)C(t)$ where $P(t)$ is the exact price index associated with the quantity index $C(t)$:

$$P(t) \equiv \left[\int_0^{n(t)} p(i,t)^{\alpha/(1-\alpha)} \, di \right]^{(1-\alpha)/\alpha}. \tag{4.2}$$

In the second stage, households allocate their expenditures across all varieties, which yields instantaneous demand functions for each variety:

$$c(i,t) = A(t) p(i,t)^{-1/(1-\alpha)}, \quad i \in [0, n(t)], \tag{4.3}$$

where $p(i,t)$ is the price of variety i and

$$A(t) = \frac{E(t)}{P(t)^{-\alpha/(1-\alpha)}} \tag{4.4}$$

is aggregate demand. To simplify notation, from now on we leave the time dependence of variables implicit when this does not generate confusion.

4.2.2 Supply

The economy is endowed with two factors. Labor is inelastically supplied by households. Each household supplies one unit of labor, and we call L the number of households as well as the total endowment of labor. Labor is chosen as numeraire. The other factor is knowledge capital in the form of blueprints required for the production of differentiated varieties. These blueprints are protected by infinitely lived patents that depreciate at the constant rate δ.

There are two sectors: production and innovation (R&D). Innovation is performed by perfectly competitive labs that invent different types of blueprints for vertically integrated processes and fragmented ones. Each of the former processes requires a blueprint with marginal cost of invention equal to k_v. Each of the latter requires two blueprints: one for an intermediate component and one for final assembly with marginal R&D costs equal to k_m and k_s, respectively, where $k_s + k_m \leq k_v$.[6] We call v, m, and s the numbers of the three types of blueprints available at time t.

As to production, varieties are supplied by monopolistically competitive firms that buy the corresponding patents from R&D labs and hire an amount of labor proportionate to output. Therefore, each firm produces under increasing returns to scale as the price of its patent generates a fixed cost and the wage bill a variable cost. Depending on the patent it has chosen to buy, a firm can enter in three alternative modes: as a vertically integrated firm, as an intermediate supplier, or as a final assembler. The first needs λ units of labor per unit of final output; the second needs $1 \leq \lambda$ units of labor per unit of intermediate component; the third needs one unit of intermediate component per unit of final output. Accordingly, fragmented production is cheaper in terms of both fixed and marginal costs. The reason is lower R&D costs and productivity gains from specialization.

Fragmented production (henceforth referred to as outsourcing) faces additional costs that result from search frictions and incomplete contracting. After buying their patents, specialized entrants of each type must find a suitable partner in a matching process that may not always end in success. Moreover, intermediate suppliers also suffer hold-up problems due to contractual incompleteness. In particular, after matching, each intermediate supplier produces a relation-specific input. This input has no value outside the relation, and its quality is unverifiable by third parties.[7] This implies that the final assembler can refuse payment after the intermediate has been produced and the parties have to bargain on the division of the joint surplus that will materialize after final assembly. This gives rise to a holdup problem insofar as the production cost of the variety-specific input, which has no alternative use at the bargaining stage, is sunk. The transaction costs involved in ex post bargaining may then cause both parties to underinvest in their contractual relation, thus reducing their joint surplus.

Specifically, define $\dot{s} = ds/dt$ and $\dot{m} = dm/dt$ as the flows of new entrants as final assemblers and suppliers, respectively, that is, the numbers of new assembler and supplier blueprints invented at time t. Let $n(\dot{s}, \dot{m}) \leq \min(\dot{s}, \dot{m})$ be a constant-return-to-scale matching function that at time t determines the number of new supplier-assembler matches given the number of entrants of each type $\dot{s}$ and $\dot{m}$. Then if we define $r \equiv \dot{m}/\dot{s}$, $\eta(r) \equiv n(\dot{s}, \dot{m})/\dot{s}$ is the matching probability of an assembler entrant, while $\eta(r)/r$ is the matching probability of a supplier entrant. Accordingly, the relative abundance of the two types of entrants determines their probabilities of being matched.

After a match is formed, each pair of firms bargains on the division of their joint surplus, given by the prospective revenues of the corresponding variety. Since both parties cannot find a replacement, there is bilateral monopoly so that they will eventually agree on a share that makes both better off than if they had not met. We denote the bargaining weight of the intermediate input producer by ω.

To summarize, in each period t, the sequence of actions is the following. First, R&D takes place, and firms choose their mode of entry by buying the corresponding patents. Second, prospective parties of an outsourcing agreement search for partners, which could end in a successful or an unsuccessful match. Unmatched entrants exit, and their blueprints are destroyed. Third, each matched intermediate producer manufactures the input needed by its partner. Fourth, parties bargain over the division of total revenues from final sales, and inputs are handed over to assemblers. Fifth, final assembly takes place, and the final goods are sold to households, together with those supplied by vertically integrated firms.

4.3 Organization and Product Variety

At time t the instantaneous equilibrium is found by solving the model backward from final production to R&D for given numbers of each type of blueprints: vertically integrated firms v, intermediate suppliers m, and final assemblers s. For production and innovation to take place at time 0, we assume that the economy is initially endowed with positive stocks of both vertically integrated and matched pairs of specialized blueprints: $v_0 > 0$ and $f_0 > 0$.[8]

4.3.1 Production

Varieties can be sold to final customers by two types of firms: vertically integrated firms and final assemblers. A typical vertically integrated firm faces a demand curve derived from equation 4.3 and a marginal cost equal to λ. It chooses its scale by maximizing its operating profit,

$$\pi_v = p_v y_v - \lambda x_v, \tag{4.5}$$

where x_v is the amount of the intermediate input produced and $y_v = x_v$ is final output. Optimal final output and price are then given by

$$x_v = y_v = A\left(\frac{\alpha}{\lambda}\right)^{1/(1-\alpha)} \tag{4.6}$$

and

$$p_v = \frac{\lambda}{\alpha}. \tag{4.7}$$

Replacing these values in equation 4.5 results in operating profit equal to

$$\pi_v = (1-\alpha)A\left(\frac{\alpha}{\lambda}\right)^{\alpha/(1-\alpha)}, \tag{4.8}$$

which is a decreasing function of the elasticity of substitution $1/(1-\alpha)$ and of the marginal cost λ.

Turning to outsourcing, there is a one-to-one equilibrium relationship between the number of matched assemblers, the number of matched intermediate suppliers, and the number of outsourced varieties, which are all equal to f. The joint surplus of a matched pair of entrants is given by the revenues from the final sales of the corresponding variety $p_s y_s$. This is divided according to the bargaining weights of the parties. Accordingly, a share $(1-\omega)$ goes to the final assembler:

$$\pi_s = (1-\omega)p_s y_s. \tag{4.9}$$

The remaining $\omega p_s y_s$ goes to the intermediate supplier.

Moving one step backward, the intermediate producer must decide how much input x_m to produce, anticipating a share of revenues $\omega p_s y_s$ while bearing a cost of x_m units of labor. Therefore, the intermediate supplier maximizes

$$\pi_m = \omega p_s y_s - x_m, \tag{4.10}$$

which implies intermediate and final outputs equal to

$$x_m = y_s = A(\alpha\omega)^{1/(1-\alpha)} \tag{4.11}$$

with associated prices

$$p_m = \frac{1}{\omega}, \quad p_s = \frac{1}{\alpha\omega}. \tag{4.12}$$

Note that $p_v/p_s = \lambda\omega$, which is the ratio of the efficiency loss of vertical integration to that of outsourcing. The former stems from the lack of specialization, the latter from intermediate underproduction due to holdup fears. Using these results in equations 4.9 and 4.10 gives the operating profits of matched final assemblers and intermediate suppliers:

$$\pi_s = (1-\omega)A(\alpha\omega)^{\alpha/(1-\alpha)} \tag{4.13}$$

and

$$\pi_m = (1-\alpha)\omega A(\alpha\omega)^{\alpha/(1-\alpha)}. \tag{4.14}$$

Finally, when both vertically integrated firms and final assemblers are active, substituting equations 4.7 and 4.12 into 4.2 and 4.4 allows us to write aggregate demand as

$$A = \frac{E}{v\left(\frac{\alpha}{\lambda}\right)^{\alpha/(1-\alpha)} + f(\alpha\omega)^{\alpha/(1-\alpha)}}, \tag{4.15}$$

where v is the number of vertically integrated firms and f is the number of matched pairs of specialized producers that are active at time t.

4.3.2 Innovation

Going backward, we reach the entry stage. Here labs invent new blueprints at marginal costs k_v, k_m, and k_s depending on the organizational modes. Their output determines the laws of motion of v and f. For vertically integrated firms, we have

$$\dot{v} = \frac{L_v^I}{k_v} - \delta v, \tag{4.16}$$

where $\dot{v} \equiv dv/dt$, L_v^I is labor employed in inventing new blueprints for vertically integrated production, $1/k_v$ is its productivity, and δ is the depreciation rate. For specialized pairs, we have

$$\dot{f} = \eta(r)\dot{s} - \delta f \quad \text{with} \quad r \equiv \frac{\dot{m}}{\dot{s}},\ \dot{s} = \frac{L_s^I}{k_s},\ \dot{m} = \frac{L_m^I}{k_m}, \tag{4.17}$$

where $\dot{f} \equiv df/dt$, L_s^I, and L_m^I are labor employed in inventing new final assembler and intermediate supplier blueprints, while $1/k_s$ and $1/k_m$ are their respective productivities.

Labs pay their researchers by borrowing at the interest rate R while knowing that the resulting patents will generate instantaneous dividends equal to the expected profits of the corresponding firms. Since specialized entrants are not sure of being matched, equations 4.13 and 4.14 imply that the expected dividends of intermediate and final assembly patents are, respectively,

$$\pi_m^e = (1-\alpha)\frac{\eta(r)}{r}\omega A(\alpha\omega)^{\alpha/(1-\alpha)} \tag{4.18}$$

and

$$\pi_s^e = \eta(r)(1-\omega)A(\alpha\omega)^{\alpha/(1-\alpha)}. \tag{4.19}$$

Then if we call J_j the asset value of a patent for $j = v, s, m$, arbitrage in the capital market implies

$$R = \frac{\pi_j^e}{J_j} + \frac{\dot{J}_j}{J_j} - \delta, \tag{4.20}$$

where $\dot{J}_j \equiv dJ_j/dt$ is the capital gain.

Due to perfect competition in R&D, patents are priced at marginal cost, which requires

$$J_j = k_j.$$

The value of a patent is therefore constant through time so that $\dot{J}_j = 0$. When substituted into equation 4.20, these results give

$$R + \delta = \frac{\pi_v}{k_v} = \frac{\pi_s^e}{k_s} = \frac{\pi_m^e}{k_m}, \tag{4.21}$$

which pins down the interest rate in the Euler, equation 4.1.

Finally, the aggregate resource constraint (or full employment condition) closes the characterization of the instantaneous equilibrium. Since labor is used in innovation and in intermediate production by both vertically integrated and specialized producers, we have $L = L_v^I + L_s^I + L_m^I + v\lambda x_v + fx_m$. By equations 4.6, 4.11, 4.16, and 4.17, the condition can be rewritten as

$$L = k_v(\dot{v} + \delta v) + k_s\dot{s} + k_m\dot{m} + v\lambda A\left(\frac{\alpha}{\lambda}\right)^{1/(1-\alpha)} + fA(\alpha\omega)^{1/(1-\alpha)}. \tag{4.22}$$

4.3.3 Equilibrium

The first thing to notice is that in any instant t, there is never simultaneous invention of both vertically integrated and specialized blueprints. This would be the case if all equalities in equation 4.21 held at the same time. This is generally impossible. To see this, consider first that new outsourcing agreements are signed only if there is new creation of both intermediate supplier and final assembler blueprints, which requires

$$\frac{\pi_m^e}{k_m} = \frac{\pi_s^e}{k_s} \Leftrightarrow r = \bar{r} \equiv \frac{k_s}{k_m}\frac{(1-\alpha)\omega}{1-\omega}, \tag{4.23}$$

where we have used equations 4.18 and 4.19. Thus, the two types of specialized blueprints have to be invented in fixed proportion. Second, if vertically integrated patents are simultaneously invented, it must be

$$\frac{\pi_v}{k_v} = \frac{\pi_s^e}{k_s} \Leftrightarrow \frac{(1-\alpha)\lambda^{-\alpha/(1-\alpha)}}{k_v} = \frac{\eta(\bar{r})(1-\omega)\omega^{\alpha/(1-\alpha)}}{k_s}.$$

Since both sides are constant, this equality is satisfied only for a zero-measure set of parameter values. Hence, in general, vertically integrated and specialized blueprints are not invented together in equilibrium. In particular, only the former are created when

$$\frac{(1-\alpha)\lambda^{-\alpha/(1-\alpha)}}{k_v} > \frac{\eta(\bar{r})(1-\omega)\omega^{\alpha/(1-\alpha)}}{k_s}, \tag{4.24}$$

and only the latter when the reverse is true.

Vertical Integration

When condition 4.24 holds, $L_s^I = L_m^I = 0$, so no new specialized blueprints are ever created: $\dot{s} = \dot{m} = 0$. As a result, the initial stocks of specialized blueprints are eroded by depreciation:

$$\dot{f} = -\delta f. \tag{4.25}$$

Then, using equations 4.6, 4.8, 4.15, and 4.21, the full employment condition, equation 4.22, and the Euler condition, equation 4.1, can be respectively rewritten as

$$L = k_v(\dot{v} + \delta v) + E\frac{v\lambda\left(\frac{\alpha}{\lambda}\right)^{1/(1-\alpha)} + f(\alpha\omega)^{1/(1-\alpha)}}{v\left(\frac{\alpha}{\lambda}\right)^{\alpha/(1-\alpha)} + f(\alpha\omega)^{\alpha/(1-\alpha)}} \tag{4.26}$$

and

$$\frac{\dot{E}}{E} = \frac{(1-\alpha)E}{k_v} \frac{\left(\frac{\alpha}{\lambda}\right)^{\alpha/(1-\alpha)}}{v\left(\frac{\alpha}{\lambda}\right)^{\alpha/(1-\alpha)} + f(\alpha\omega)^{\alpha/(1-\alpha)}} - \rho - \delta. \tag{4.27}$$

Equations 4.25, 4.26, and 4.27 form a three-dimensional dynamic system that has a unique steady state in E, v, f, and is saddle-path stable (see the appendix). The steady-state values can be obtained by solving the system after setting $\dot{E} = \dot{v} = \dot{f} = 0$:

$$E_v^* = \frac{\rho+\delta}{\delta+\alpha\rho}L, \quad v_v^* = \frac{1-\alpha}{\delta+\alpha\rho}\frac{L}{k_v}, \quad f_v^* = 0. \tag{4.28}$$

Due to depreciation, the steady-state mass of vertically integrated firms is maintained through ongoing innovation. When all firms are destroyed instantaneously ($\delta = 1$), these results are the same as in the dynamic model of Grossman and Helpman (1991). In addition, when there is no time discounting ($\rho = 0$), they are the same as in the static model by Grossman and Helpman (2002).

Outsourcing

When condition 4.24 does not hold, $L_v^I = 0$, so no vertically integrated blueprints are ever created, implying that their initial stock is depleted by depreciation:

$$\dot{v} = -\delta v. \tag{4.29}$$

Using equations 4.13, 4.14, 4.15, 4.17, 4.21, and 4.23, the full employment condition, 4.22, and the Euler condition, 4.1, can be respectively rewritten as

$$L = \frac{k_s + k_m\bar{r}}{\eta(\bar{r})}(\dot{f} + \delta f) + E\frac{v\lambda\left(\frac{\alpha}{\lambda}\right)^{1/(1-\alpha)} + f(\alpha\omega)^{1/(1-\alpha)}}{v\left(\frac{\alpha}{\lambda}\right)^{\alpha/(1-\alpha)} + f(\alpha\omega)^{\alpha/(1-\alpha)}} \tag{4.30}$$

and

$$\frac{\dot{E}}{E} = \frac{\eta(\bar{r})(1-\omega)E}{k_s} \frac{\left(\frac{\alpha}{\lambda}\right)^{\alpha/(1-\alpha)}}{v\left(\frac{\alpha}{\lambda}\right)^{\alpha/(1-\alpha)} + f(\alpha\omega)^{\alpha/(1-\alpha)}} - \rho - \delta. \tag{4.31}$$

This dynamic system 4.29-4.30-4.31 has a unique steady state, and it is saddle-path stable (see the appendix).[9] The associated level of expenditures and numbers of firms can be obtained by solving the system after setting $\dot{E} = \dot{f} = \dot{v} = 0$:

$$E^* = \frac{\rho + \delta}{\delta + \omega\alpha\rho} L, \quad f^* = \eta(\bar{r}) \frac{1 - \omega}{\delta + \omega\alpha\rho} \frac{L}{k_s}, \quad v^* = 0. \tag{4.32}$$

Note that the number of active outsourcing pairs f_s^* depends on the matching probability of assembler entrants $\eta(\bar{r})$. Again, due to depreciation, the steady-state masses of firms are maintained through ongoing innovation. Given equation 4.23, imposing $\dot{f} = 0$ and $r = \bar{r}$ in equation 4.17 allows us to determine the flows of assembler and intermediate entrants in each period:

$$\dot{s}^* = \frac{\delta(1 - \omega)}{\delta + \omega\alpha\rho} \frac{L}{k_s}, \quad \dot{m}^* = \frac{\delta\omega(1 - \alpha)}{\delta + \omega\alpha\rho} \frac{L}{k_m}. \tag{4.33}$$

Note that the static equilibrium in Grossman Helpman (2002) corresponds to the steady state of our model when $\rho = 0$ (no time discounting) and $\delta = 1$ (all firms die every period).

4.3.4 Comparative Statics

Economic intuition on the driving forces behind the choice of the organizational mode is boosted by remembering that $\alpha = (1 - 1/\sigma)$ and rewriting equation 4.24 as

$$\underbrace{\frac{1}{\eta(\bar{r})}}_{\text{probability } v/s} \quad \underbrace{\frac{1/\sigma}{1 - \omega}}_{\text{profit share } v/s} \quad \underbrace{\left(\frac{\lambda}{1/\omega}\right)^{1-\sigma}}_{\text{revenues } v/s} > \underbrace{\frac{k_v}{k_s}}_{\text{R\&D cost } v/s} \tag{4.34}$$

with

$$\left.\frac{d\eta(r)}{dr}\right|_{r=\bar{r}} > 0, \quad \bar{r} = \underbrace{\frac{k_s}{k_m}}_{\text{R\&D cost } s/m} \quad \underbrace{\frac{1/\sigma}{1/\omega - 1}}_{\text{margin } s/m}. \tag{4.35}$$

$$\frac{\bar{r}}{\eta(\bar{r})} \frac{k_m}{k_s} \frac{1/\omega - 1}{1/\sigma} \frac{1/\sigma}{1 - \omega} \left(\frac{\lambda}{1/\omega}\right)^{1-\sigma} > \frac{k_v}{k_s} \quad \omega(\lambda\omega)^{\sigma-1}\eta(\bar{r})/\bar{r} < k_m/k_v.$$

If condition 4.34 holds, all entrants choose vertical integration. Of course, this is the case when the relative benefits of vertical integration dominate the relative costs. The left-hand side of equation 4.34 shows that the former come from three sources: the fact that specialized final assemblers face matching uncertainty whereas vertically integrated firms do not $(1/\eta(\bar{r}))$, the relative profit margin $((1/\sigma)/(1-\omega))$, and the relative total revenues $((\lambda\omega)^{1-\sigma})$. The right-hand side shows instead that the relative costs of vertical integration derive from the costs of innovation (k_v/k_s). Then vertical integration is chosen when specialized final assemblers have low chances of finding specialized intermediate suppliers (small $\eta(\bar{r})$); when product differentiation is strong, so that the profit share of revenues of vertically integrated firms is large (large $1/\sigma$) relative to the share appropriated by final assemblers through bargaining (small $1-\omega$); when vertically integrated revenues are relatively large due to small gains from specialization (small λ) and severe intermediate underproduction caused by weak supplier bargaining power (small ω); and when the blueprints for vertically integrated production are relatively cheap compared with those for specialized assembly (small k_v/k_s). Expressions 4.35 highlight the fact that the matching probability of specialized assemblers itself depends on the relative R&D costs (k_s/k_m) and the relative profit margin of final assemblers and intermediate suppliers $((1/\sigma)/(1/\omega-1))$. When their R&D costs are relatively small and the profit margin is relatively large, the entrants are mostly final assemblers, reducing their probability $\eta(\bar{r})$ of being matched. This makes condition 4.34 easier to fulfill.

All parameters have unambiguous impacts on the propensity to vertical integration except σ and ω. Larger σ unambiguously fosters outsourcing provided that $\lambda\omega > 1$. Otherwise that happens only if σ is small enough. This can be understood by plugging $\bar{r}$ from equation 4.35 in 4.34 and rewriting the resulting condition as $\omega(\lambda\omega)^{\sigma-1}\eta(\bar{r})/\bar{r} < k_m/k_v$. As larger σ decreases $\bar{r}$, it always raises the matching probability of intermediate suppliers $\eta(\bar{r})/\bar{r}$. On the other hand, larger σ amplifies the revenue advantage of final assemblers $(\lambda\omega)^{\sigma-1}$ if their relative marginal costs are lower $(\lambda\omega > 1)$ and their revenue disadvantage if their relative marginal costs are higher $(\lambda\omega < 1)$. This is because larger σ makes demand more sensitive to small price differences. In the former case, both effects work in the direction of fostering outsourcing. In the latter, the relative revenue effect favors vertical integration, the more so the larger is σ.

As to ω, stronger supplier bargaining power also has two opposite effects: it promotes intermediate production but at the same time reduces the matching probability of intermediate suppliers. While the former effect fosters outsourcing, the latter hampers it. Favorable scenarios for outsourcing strike a balance between the two effects. This happens for values of ω that are neither too small nor too large. Too see this, use equation 4.24 to derive the following condition for outsourcing to dominate vertical integration:

$$\gamma \equiv \frac{\eta(\bar{r})(1-\omega)k_v}{(1-\alpha)k_s}(\omega\lambda)^{\alpha/(1-\alpha)} > 1.$$

Then, recalling the value of $\bar{r}$ from equation 4.23, γ is an increasing function of ω if and only if

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

where ε_η is the elasticity of $\eta(r)$ with respect to r. Given our assumptions of the matching function, we have $0 < \varepsilon_\eta < 1$, and therefore γ is increasing (decreasing) in ω when this is very small (large). This implies a relationship between the incentives to outsource and the bargaining power of intermediate suppliers that has an inverted-U shape.

All results so far mirror those in Grossman and Helpman (2002). Parameters specific to our dynamic setting play a role when we turn to steady-state outcomes. Most parameters have the same impact under both vertical integration and outsourcing. Larger elasticity of substitution (larger σ, i.e., larger α) reduces both expenditures and variety. The reason is thinner profit margins, which discourage innovation and force firms to employ more workers to cover their fixed R&D costs through large-scale production. Faster depreciation (larger δ) also negatively affects both expenditures and variety as it reduces the incentives to innovate and diverts labor from alternative use. Differently, stronger time preference (larger ρ) has a negative impact on product variety but a positive one on expenditures since it biases intertemporal decisions toward consumption and away from saving. Finally, higher costs of innovation (larger k_v, k_s, or k_m) have no impact on expenditures and a negative impact on product variety, whereas a larger economy (larger L) supports both higher expenditures and more product varieties.

The bargaining weight ω is, of course, peculiar to outsourcing. Larger ω is associated with smaller expenditures. Its impact on product variety is instead ambiguous depending on the specific functional form of $\eta(.)$. Given equation 4.32, f^* is an increasing function of ω if and only if

$$\varepsilon_\eta > \frac{\delta\omega + \omega\alpha\rho}{\delta + \omega\alpha\rho}.$$

Since $0 < \varepsilon_\eta < 1$, this condition holds for $\omega = 0$ and is violated for $\omega = 1$. Hence, product development is higher for values of ω that are neither too small nor too large. This is because larger ω encourages more intermediate entry (larger $\bar{r}$) and thus increases the matching probability of assemblers (larger $\eta(\bar{r})$). On the other hand, it reduces their share of surplus once matched. Finally, larger ω always leads to faster convergence to steady state (see the appendix).

4.4 Conclusion

We have proposed a theoretical framework to shed light on some aspects of the new approach to innovation that relies on increasingly global networks of partners. In particular, conditional on the outsourcing of innovation occurring, we have studied how alternative organizational forms in production arise and how these affect the incentives to innovate.

The underlying idea is that the outsourcing of production brings about gains in terms of both lower costs of R&D and higher benefits of specialization in upstream and downstream production. It is, however, associated with larger transaction costs due to incomplete contracts and holdup problems. We have shown that the bargaining power of upstream and downstream parties at the production stage feeds back to R&D incentives, thus affecting innovation. The reason is that specialized production also requires specialized R&D, whose returns depend on the bargaining outcomes. Product development is best served by contracts in which the bargaining power of upstream suppliers is neither too weak nor too strong.

The proposed framework combines the new features of outsourcing contracts as in Grossman and Helpman (2002) with the well-known model of growth under horizontal differentiation as in Grossman and Helpman (1991). While one might have guessed that the combination would be too complex to analyze, we have shown that this is not the case. Indeed, as discussed by Naghavi and Ottaviano (2005a, 2005b), the framework is simple enough to be extended to model endogenous growth and study how the organizational choices of firms affect the long-run growth rate of the economy even in the presence of heterogenous firms. These are interesting directions for future research.

Appendix: Stability of Steady States

We show that in section 4.3.3 the steady states with vertical integration and outsourcing are both saddle-path stable. Consider the former case. The corresponding dynamic system is formed by equations 4.27, 4.26, and 4.25. The Jacobian matrix evaluated at equation 4.28 is

$$D_v \equiv \begin{bmatrix} \delta+\rho & -\frac{(\delta+\rho)^2 k_v}{1-\alpha} & -\frac{(\delta+\rho)^2 k_v}{1-\alpha}(\lambda\omega)^{\alpha/(1-\alpha)} \\ -\frac{\alpha}{k_v} & -\delta & \frac{(\delta+\rho)\alpha(1-\omega)}{1-\alpha}(\lambda\omega)^{\alpha/(1-\alpha)} \\ 0 & 0 & -\delta \end{bmatrix}$$

with eigenvalues

$$\lambda_{1,2}^v = \frac{\rho}{2} \pm \frac{\rho}{2}\sqrt{1+4\frac{(\delta+\rho)(\delta+\alpha\rho)}{\rho^2(1-\alpha)}}; \quad \lambda_3^v = -\delta.$$

Consider now the outsourcing case. The associated dynamic system is formed by equations 4.31, 4.29, and 4.30. The Jacobian matrix evaluated at steady state in equation 4.32 is given by

$$D \equiv \begin{bmatrix} \delta+\rho & -\frac{(\delta+\rho)^2 k_s}{\eta(\bar{r})(1-\omega)(\lambda\omega)^{\alpha/(1-\alpha)}} & -\frac{(\delta+\rho)^2 k_s}{\eta(\bar{r})(1-\omega)} \\ 0 & -\delta & 0 \\ -\frac{\eta(\bar{r})\alpha\omega(1-\omega)}{k_s(1-\alpha\omega)} & -\frac{(\delta+\rho)\alpha(1-\omega)}{(1-\alpha\omega)(\lambda\omega)^{\alpha/(1-\alpha)}} & -\delta \end{bmatrix}.$$

The associated eigenvalues are independent from $\eta(\bar{r})$:

$$\lambda_{1,2} = \frac{\rho}{2} \pm \frac{\rho}{2}\sqrt{1+4\frac{(\delta+\rho)(\delta+\omega\alpha\rho)}{\rho^2(1-\alpha\omega)}}; \quad \lambda_3 = -\delta.$$

Then, all the rest given, the speed of convergence to steady state is increasing in ω.

Notes

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1. See Helpman (2006) for an overview of recent models of firm involvement in foreign activities and Gattai (2005) for a survey of additional applications of the theory of the firm to international trade issues.

2. Marin and Verdier (2003) as well as Antras (2003) argue that within a vertically integrated firm, the agreements among stakeholders are also incomplete. This approach differs from the transaction-cost approach adopted by Grossman and Helpman (2002, 2003, 2005) in the wake of Williamson (1985). It is, instead in line with the property rights theory proposed by Grossman and Hart (1986) and further developed by Hart and Moore (1990), according to which holdup problems arise also within integrated firms with their relevance depending on the allocation of property rights between stakeholders.

3. Specifically, when all firms are destroyed instantaneously, our results are the same as in the dynamic model by Grossman and Helpman (1991). In addition, when there is no time discounting, they are the same as in the static model by Grossman and Helpman (2002).

4. Our analysis is performed under the assumption of constant-returns-to-scale matching. Grossman and Helpman (2002) also consider the case of increasing returns to scale and show how matching externalities may generate multiple stable steady states. We do not cover this case but note that with explicit transitionary dynamics and multiple stable steady states, history ("initial conditions") or expectations ("initial beliefs") would determine the steady state that is eventually reached, depending on the speed of adjustment and the strength of the externalities (Ottaviano 2001).

5. The stability analysis is presented in the appendix, which reports the eigenvalues of the dynamic systems. Together with the steady-state values in the main text, the eigenvalues allow one to derive the (unreported) adjustment paths following standard techniques.

6. This assumption captures the idea that the coordination of research teams is more complex when their aim is to create vertically integrated blueprints. In other words, the governance costs of R&D labs are higher for vertically integrated than for specialized blueprints. In equilibrium, such assumption will prevent vertically integrated firms from buying inputs from specialized suppliers.

7. As in Grossman and Helpman (2002, 2003, 2005), unobservable input quality is an issue to the extent that only high-quality inputs can be processed, whereas low-quality inputs are useless even though freely supplied.

8. The zero-measure case with $v_0 > 0$ and $f_0 = 0$ is discussed in section 4.3.3 for comparison with the static setup.

9. In the static model by Grossman and Helpman (2002), the outcome such that all firms are vertically integrated remains an equilibrium even when condition 4.24 is violated. In particular, it is a self-fulfilling expectation equilibrium supported by the common belief that no specialized firm will ever enter the market. As this implies zero matching probability, no specialized firm will indeed enter, thus making the common belief self-fulfilling. This equilibrium is, however, unstable: any specialized entry would make all firms abandon vertical integration. In our dynamic model, the positive initial stock $f_0 > 0$ rules out the possibility of such a self-fulfilling equilibrium. This would be viable only in the zero-measure case where $f_0 = 0$ and $v_0 > 0$.

References

Acemoglu, D., P. Aghion, and F. Zilibotti. (2006). Distance to Frontier, Selection, and Economic Growth. *Journal of the European Economic Association* 4, 37–74.

Antras, P. (2003). Firms, Contracts, and Trade Structure. *Quarterly Journal of Economics* 118, 1375–1418.

Antras, P., and E. Helpman. (2004). Global Sourcing. *Journal of Political Economy* 112, 552–580.

Engardio, P., and B. Einhorn. (2005). Outsourcing Innovation. *Business Week*, March 21.

Feenstra, R. (1998). Integration of Trade and Disintegration of Production in the Global Economy. *Journal of Economic Perspectives* 12, 31–50.

Feenstra, R., and G. Hanson. (2003). Ownership and Control in Outsourcing to China: Estimating the Property-Rights Theory of the Firm. Mimeo., University of California.

Feenstra, R., and G. Hanson. (2004). Ownership and Control in Outsourcing to China: Estimating the Property-Rights Theory of the Firm. Working paper no. 10198, National Bureau of Economic Research.

Gattai, V. (2005). From the Theory of the Firm to FDI and Internalization: A Survey. *FEEM Nota di Lavoro*, 51.05.

Grossman, S., and O. Hart. (1986). The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration. *Journal of Political Economy* 94, 691–719.

Grossman, G., and E. Helpman. (1991). *Innovation and Growth in the Global Economy*. Cambridge Mass.: MIT Press.

Grossman, G., and E. Helpman. (2002). Integration vs. Outsourcing in Industry Equilibrium. *Quarterly Journal of Economics* 117, 85–120.

Grossman, G., and E. Helpman. (2003). Outsourcing versus FDI in Industry Equilibrium. *Journal of European Economic Association* 1, 317–327.

Grossman, G., and E. Helpman. (2005). Outsourcing in a Global Economy. *Review of Economic Studies* 72, 135–159.

Hart, O., and J. Moore. (1990). Property Rights and the Nature of the Firm. *Journal of Political Economy* 98, 1119–1158.

Helpman, E. (2006). Trade, FDI, and the Organization of Firms. Working paper no. 12091, National Bureau of Economic Research.

Lai, E., R. Riezman, and P. Wang. (2005). Outsourcing of Innovation. Mimeo., University of Iowa.

McLaren, J. (2000). Globalisation and Vertical Structure. *American Economic Review* 90, 1239–1254.

Marin, D., and T. Verdier. (2003). Globalization and the "New Enterprise." *Journal of the European Economic Association* 1, 337–344.

Naghavi, A., and G. Ottaviano. (2005a). Outsourcing and Growth. Mimeo., Università di Bologna.

Naghavi, A., and G. Ottaviano. (2005b). Outsourcing and Industry Dynamics with Heterogeneous Firms. Mimeo., Università di Bologna.

Ottaviano, G. (2001). Monopolistic Competition, Trade, and Endogenous Spatial Fluctuations. *Regional Science and Urban Economics* 31, 51–77.

Williamson, O. E. (1985). *The Economic Institutions of Capitalism*. New York: Free Press.