

DISCUSSION PAPER SERIES

No. 5925

OUTSOURCING, COMPLEMENTARY INNOVATIONS AND GROWTH

Alireza Naghavi and
Gianmarco I P Ottaviano

INTERNATIONAL TRADE



Centre for **E**conomic **P**olicy **R**esearch

www.cepr.org

Available online at:

www.cepr.org/pubs/dps/DP5925.asp

OUTSOURCING, COMPLEMENTARY INNOVATIONS AND GROWTH

Alireza Naghavi, Università di Modena
Gianmarco I P Ottaviano, Università di Bologna and CEPR

Discussion Paper No. 5925
November 2006

Centre for Economic Policy Research
90–98 Goswell Rd, London EC1V 7RR, UK
Tel: (44 20) 7878 2900, Fax: (44 20) 7878 2999
Email: cepr@cepr.org, Website: www.cepr.org

This Discussion Paper is issued under the auspices of the Centre's research programme in **INTERNATIONAL TRADE**. Any opinions expressed here are those of the author(s) and not those of the Centre for Economic Policy Research. Research disseminated by CEPR may include views on policy, but the Centre itself takes no institutional policy positions.

The Centre for Economic Policy Research was established in 1983 as a private educational charity, to promote independent analysis and public discussion of open economies and the relations among them. It is pluralist and non-partisan, bringing economic research to bear on the analysis of medium- and long-run policy questions. Institutional (core) finance for the Centre has been provided through major grants from the Economic and Social Research Council, under which an ESRC Resource Centre operates within CEPR; the Esmée Fairbairn Charitable Trust; and the Bank of England. These organizations do not give prior review to the Centre's publications, nor do they necessarily endorse the views expressed therein.

These Discussion Papers often represent preliminary or incomplete work, circulated to encourage discussion and comment. Citation and use of such a paper should take account of its provisional character.

Copyright: Alireza Naghavi and Gianmarco I P Ottaviano

ABSTRACT

Outsourcing, Complementary Innovations and Growth*

This paper analyzes the organization of firms in a dynamic setting with endogenous growth to shed light on the link between economic growth and the parallel creation and adoption of complementary innovations by independent labs and plants. 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 into innovation and growth. Our dynamic perspective reveals a tension between the static and dynamic effects of outsourcing. The reason is that firms make their organizational choices weighting the higher searching and contracting costs of outsourcing against the higher entry and foregone specialization costs of vertical integration. In so doing, they neglect the effects of their choices on innovation and growth. Hence, when outsourcing is selected, the static gains from specialized production may at times be associated with relevant dynamic losses for consumers.

JEL Classification: D91, L14, L23 and O32

Keywords: complementary innovations, growth, incomplete contracts, organization of firms, outsourcing and welfare

Alireza Naghavi
Università di Modena e Reggio Emilia
Dipartimento di Economia Politica
Viale Berengario 51
I-41100 Modena
ITALY
Email: naghavi@unimore.it

Gianmarco I P Ottaviano
Dip. di Scienze Economiche
Università di Bologna
Strada Maggiore 45
40125 Bologna
ITALY
Email: ottavian@economia.unibo.it

For further Discussion Papers by this author see:
www.cepr.org/pubs/new-dps/dplist.asp?authorid=153419

For further Discussion Papers by this author see:
www.cepr.org/pubs/new-dps/dplist.asp?authorid=125330

*We are grateful to Elhanan Helpman, Dalia Marin, Thierry Verdier and seminar participants to the 2nd Workshop on Globalization and Contracts at PSE for useful comments. Ottaviano gratefully acknowledges financial support from MIUR.

Submitted 06 October 2006

1 Introduction

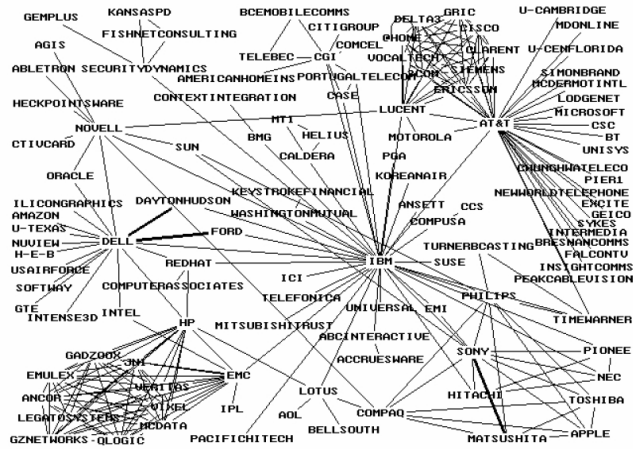
The defragmentation of the production process through outsourcing has experienced a remarkable growth in the last three decades (Feenstra, 1998). It is the most recent form of division of labor used as a business strategy to exploit gains from specialization. Today, outsourcing is no longer a concept limited to manufacturing and services. Given the complexities of today's technologies and supplier chains, farming out R&D serves as a rule for sustainable competitive advantage and survival in in the global market. In fact, reports on firms simply outsourcing R&D no longer seem as newsworthy. The key to success tends to increasingly hinge on the utilization of creativity and skills of specialized workers and engineers around the world linked in 'global innovation networks'. An example on two giants of the computer industry, Apple and IBM, helps clarify the concept. While IBM has adopted an 'unbundling' business strategy that goes as far back as 1969, Apple has insisted on maintaining the production of its own hardware and software in house.¹ The IBM family today consists of some of the fastest growing names in the PC computer industry such as Dell and Hewlett-Packard Co. as well as leading software and hardware producers such as Microsoft and Intel. While all members of the IBM family engage in the outsourcing of R&D, outsourcing production has created a market for complementary innovations giving rise to a complex network of innovators that has helped IBM enjoy a much more significant role in the computer industry than Apple.² This has been possible through a simple division of labor, which in turn has instigated a division of knowledge creation. Figure 1 shows the depth of IBM's global innovation networks in the computer industry compared to that of Apple (Tomlinson, 1999).

The aim of the present paper is to explore the implications of fragmented production for the emergence of global innovation networks and their performance in terms of growth and welfare. The central idea is that in a dynamic framework outsourcing intermediate production to upstream suppliers creates a demand for upstream R&D, which in turn leads to the division of intellectual property between upstream and downstream patents. As a result, when the production chain is

¹WALL STREET JOURNAL (1969).

²See Engardio and Einhorn (2005).

Figure 1: Innovation Networks in the Computer Industry



Source: Tomlinson (1999)

fragmented among several independent specialized firms, global networks of innovators emerge and growth is sustained by the simultaneous creation and adoption of complementary upstream and downstream innovations. Our focus is on situations in which R&D is always carried out by independent laboratories and technological knowledge is not fully appropriable, hence the decision to outsource production generates externalities that may lead to a misallocation of R&D financing between individual ventures and global networks of innovators.³

There are few existing contributions that are strictly related to this paper. 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. By highlighting the effects of fragmented production on innovation when R&D is always outsourced, our model complements both contributions. Turning to production, we model the choice

³Our parallel paper Naghavi and Ottaviano (2006) explores the organizational choice of firms in a dynamic framework in the presence of heterogeneous firms.

on whether to fragment it or not in the wake of recent research that investigates outsourcing in an industry equilibrium when contracts are incomplete due to the lack of ex-post verifiability by third parties. The main contributions of this literature are surveyed by Helpman (2006). In particular, the decision on whether production should be kept in-house or outsourced has been explored by McLaren (2000) as well as Grossman and Helpman (2002) for a closed economy, and by Antras (2003), Grossman and Helpman (2003) as well as Feenstra and Hanson (2004) for an open economy.

All the foregoing contributions focus on the static effects of outsourcing. We investigate instead its dynamic effects. In so doing, we introduce endogenous growth into the static outsourcing model by Grossman and Helpman (2002). In their model firms can enter as intermediate suppliers, final assemblers or vertically integrated firms. Along the production chain vertical integration bears additional costs due to more complex governance and limited specialization. Outsourcing incurs, instead, additional costs of searching and contracting with matched partners. To introduce endogenous growth in this framework, we build on the model of horizontal innovation by Grossman and Helpman (1991). In particular, we assume that, whatever firms' organizational choices, to enter the market they need blueprints for production. The blueprints come in three forms designed specifically for each type of entrant. All blueprints are invented by independent perfectly competitive labs and are protected by infinitely lived patents. Labs benefit from learning as cumulated experience in vertically integrated and specialized production reduces the invention costs of the corresponding blueprints. Controlling for learning effects, the creation of blueprints for vertically integrated production is more costly reflecting the higher complexity of the corresponding innovation process.

Our dynamic perspective reveals a tension between the static and dynamic implications of outsourcing. The reason is that firms make their organizational choices weighting the higher searching and contracting costs of outsourcing against the higher governance and foregone specialization costs of vertical integration. In so doing, they neglect the effects of their choices on innovation and growth. Hence, when outsourcing is selected, the static gains from specialized production may at times be associated with relevant dynamic losses for consumers. Whether this happens or not depends on sector characteristics. In particular, both firms and consumers favor outsourcing when there are

substantial gains from specialization and the ex post bargaining weights of intermediate suppliers and final producers tend to mirror the relative incentives of labs to create the corresponding blueprints. When this is the case, search and hold-up frictions are minimized. Thus, in sectors in which the R&D costs of intermediate blueprints are large (resp. small) with respect to the R&D cost of final blueprints, outsourcing is likely to be welfare improving if the bargaining weight of intermediate suppliers is also large (resp. small) with respect to the bargaining weight of final assemblers. These results are amplified in sectors with pronounced product differentiation.

The rest of the paper is organized as follows. Section 2 presents the basics of our model. Section 3 investigates the industrial equilibrium under endogenous growth. Section 4 discusses the consequences of firms' organizational choices on economic growth. Section 5 studies their welfare implications. Section 6 concludes.

2 The Model

2.1 Consumption and Saving

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

$$U = \int_0^{\infty} e^{-\rho t} \ln C(t) dt, \quad (1)$$

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 number of varieties produced, and α is an inverse measure of the degree of product differentiation between varieties. Households have perfect foresight and they can borrow and lend freely in a perfect capital market at instantaneous interest rate $R(t)$.

Using multi-stage budgeting to solve their utility maximization problem, households first allocate

their income flow between savings and expenditures. This yields a time path of total expenditures $E(t)$ that obeys the Euler equation of a standard Ramsey problem:

$$\frac{\dot{E}(t)}{E(t)} = R(t) - \rho, \quad (2)$$

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 $C(t)$:

$$P(t) \equiv \left[\int_0^{n(t)} p(i, t)^{\alpha/(1-\alpha)} di \right]^{(1-\alpha)/\alpha}. \quad (3)$$

Households then allocate their expenditures across all varieties, which yields the instantaneous demand function

$$c(i, t) = A(t)p(i, t)^{-1/(1-\alpha)} \quad i \in [0, n(t)] \quad (4)$$

for each variety. In (4) $p(i, t)$ is the price of variety i and

$$A(t) = \frac{E(t)}{P(t)^{-\alpha/(1-\alpha)}} \quad (5)$$

is aggregate demand. Throughout the rest of the paper, we leave the time dependence of variables implicit when this does not generate confusion.

2.2 Innovation and Production

There are two factors of production in the economy. Labor is inelastically supplied by households. Each household supplies one unit of labor; we can hence use a single index L to refer to 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, the creation of which leads to the production of differentiated varieties. While the length of patents on the blueprints is infinite, they depreciate at a constant rate δ .

There are two sectors, production and innovation (R&D). Perfectly competitive labs invent different types of blueprints depending on the corresponding production processes. Vertically integrated

processes need a single blueprint. Fragmented processes require two blueprints: one for the intermediate component and one for the final product. Firms enter by buying patents from the R&D labs. A firm can thus choose the type of patent and enter as a vertically integrated firm, an intermediate supplier or a final assembler. The number of each of these types of blueprints available at time t will be referred to as v , m , and s respectively. The marginal cost of production for vertically integrated firms is $\lambda \geq 1$ units of labor, whereas specialized intermediate producers only require 1 unit of labor per unit of input. Specialized final assemblers in turn need one unit of the intermediate component produced by their partner for each unit of the final good. Accordingly, outsourcing leads to productivity gains that stem from specialization in production.

Labs invent new blueprints at a marginal cost that depends on their types. R&D faces a learning curve, a larger number of a certain type of blueprints successfully introduced in the past makes researchers more productive in inventing that type of blueprint. For specialized blueprints, what matters is not only the number of invented patents, but also the number f of those that have actually been matched and used in production. In particular, as in Grossman and Helpman (1991), we consider a linear learning curve such that the marginal costs of innovation are k_v/v , k_m/f , and k_s/f (with k_v , k_m and k_s all positive) depending on the type of the blueprints.⁴ Given this functional form, some initial stocks of implemented blueprints is needed to have finite costs of innovation at all times. We call them $v_0 > 0$ and $f_0 > 0$ for vertically integrated and specialized blueprints respectively. We finally assume that $k_s + k_m \leq k_v$ to capture the idea that the governance costs of more complex R&D for vertically integrated blueprints are higher than those of a combined effort in specialized R&D.

⁴The assumed shape of the learning curve serves analytical solvability and the comparison with Grossman and Helpman (1991). In equilibrium it yields a ‘size effect’, meaning that larger countries grow faster. As this prediction runs against the empirical evidence, the size effect could be removed by assuming that the intensity of the learning spillover is lower, i.e. k_v/v^ξ , k_m/f^ξ , and k_s/f^ξ with $0 < \xi < 1$ (Jones, 1995).

2.3 Matching and Bargaining

Outsourcing also faces additional costs that result from search frictions and incomplete contracts. After buying a patent, specialized entrants of each type must bear a search cost of finding a suitable partner in a matching process that may not always end in success. Matched intermediate suppliers also suffer hold-up problems as they each produce a relation-specific input. This input has no value outside the relation and its quality is too costly to observe by courts. Thus, the final assembler can refuse payment after the input has been produced. This gives rise to a hold-up problem in so far as, the variety-specific input having no alternative use at the bargaining stage, its production cost is sunk. The transaction costs involved in ex-post bargaining may then cause both parties to underinvest in their contractual relation, reducing their joint profits.⁵

Let expressions $\dot{s} = ds/dt$ and $\dot{m} = dm/dt$ represent the flows of new final assembler and intermediate supplier entrants respectively. The number of new upstream-downstream matches at time t is determined by the following constant returns to scale matching function: $f(\dot{s}, \dot{m}) = \min(\dot{s}, \dot{m})$. If we define $r \equiv \dot{m}/\dot{s}$, the matching probability of a final assembler entrant and an intermediate supplier entrant can then be rewritten as $\eta(r) \equiv f(\dot{s}, \dot{m})/\dot{s}$ and $\eta(r)/r$ respectively. The blueprints that correspond to unmatched entrants are instantaneously destroyed.

After a successful match, intermediate suppliers produce their relation-specific inputs. Then each matched pair bargains on the division of its joint surplus, given by the prospective revenues from the sales of the corresponding variety. Since neither party has an outside option, 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 .

⁵This approach is similar to the transaction-cost approach adopted by Grossman and Helpman (2002, 2003). Marin and Verdier (2003) as well as Antras (2003) take on a different approach in line with the property rights theory of Grossman and Hart (1986) and Hart and Moore (1990), which states that agreements among stakeholders within a vertically integrated firm are also incomplete.

2.4 Timing

In each period t the following sequence of actions take place. Independent labs engage in R&D to innovate new patents corresponding to vertically integrated firms, upstream specialized intermediate producers and downstream specialized assemblers. In the production sector firms choose their mode of entry by purchasing the respective blueprints. Firms who have purchased specialized blueprints search for partners to form an upstream-downstream chain. Their effort could end in a successful or an unsuccessful match. Each matched intermediate producer manufactures the input needed by its partner, while unmatched entrants exit and their patents are destroyed. Once input production is completed, the outsourcing pair bargain over the share of total revenues from final sales that goes to each partner and inputs are handed over to assemblers. Final assembly then takes place and the final products are sold to households together with those supplied by vertically integrated firms.

3 Industrial Organization

3.1 Production

At time t the instantaneous equilibrium is found by solving the model backwards from final production to R&D given the number of blueprints invented for each organizational mode. 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 (4) and a marginal cost equal to λ . It chooses its scale by maximizing its operating profit

$$\pi_v = p_v y_v - \lambda x_v, \tag{6}$$

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

$$x_v = y_v = A \left(\frac{\alpha}{\lambda} \right)^{\frac{1}{1-\alpha}} \tag{7}$$

and

$$p_v = \frac{\lambda}{\alpha}. \tag{8}$$

Replacing these values in (6) results in operating profit equal to

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

which is an increasing function of product differentiation $(1 - \alpha)$ and a decreasing function of the marginal cost (λ) .

Turning to the outsourcing mode, 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; they 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 two parties. Accordingly, a share $(1 - \omega)$ goes to the final assembler giving operating profits of

$$\pi_s = (1 - \omega) p_s y_s, \quad (10)$$

and the remaining share ω goes to the intermediate supplier. The latter must decide in the previous stage how much input x_m to produce anticipating this share, which incurs a cost of x_m units of labor. Therefore, it maximizes

$$\pi_m = \omega p_s y_s - x_m, \quad (11)$$

which implies an intermediate and final output equal to

$$x_m = y_s = A (\alpha \omega)^{\frac{1}{1-\alpha}} \quad (12)$$

with associated final price

$$p_s = \frac{1}{\alpha \omega}. \quad (13)$$

Using these results in (10) and (11), and recalling that specialized intermediate and final entrants face probabilities $\eta(r)$ and $\eta(r)/r$ of being matched, their expected profits are respectively:

$$\pi_s^e = \eta(r) (1 - \omega) A (\alpha \omega)^{\frac{\alpha}{1-\alpha}} \quad (14)$$

and

$$\pi_m^e = (1 - \alpha) \frac{\eta(r)}{r} \omega A (\alpha \omega)^{\frac{\alpha}{1-\alpha}}. \quad (15)$$

Substituting (8) and (13) into (3) and (5) allows us to write aggregate demand as

$$A = \frac{E}{v \left(\frac{\alpha}{\lambda}\right)^{\frac{\alpha}{1-\alpha}} + f (\alpha\omega)^{\frac{\alpha}{1-\alpha}}}, \quad (16)$$

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 .

3.2 Innovation

In the entry stage, the output from the R&D labs determines the laws of motion of v and f . For vertically integrated firms, we have

$$\dot{v} = \frac{vL_v^I}{k_v} - \delta v \quad (17)$$

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

$$\dot{f} = \eta(r) \dot{s} - \delta f \quad \text{with} \quad r \equiv \frac{\dot{m}}{\dot{s}}, \quad \dot{s} = \frac{fL_s^I}{k_s}, \quad \dot{m} = \frac{fL_m^I}{k_m} \quad (18)$$

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, and f/k_s and f/k_m are their respective productivities.

Learning implies that the values of blueprints are not constant. As innovation cumulates, it becomes increasingly cheaper to create new patents. Being priced at marginal cost, their values fall through time. Specifically, if we call J_j the asset value of a patent, patents are priced at marginal cost due to perfect competition in R&D requiring $J_v = k_v/v$, $J_m = k_m/f$ and $J_s = k_s/f$. This implies

$$\frac{\dot{J}_v}{J_v} = -\frac{\dot{v}}{v}, \quad \frac{\dot{J}_m}{J_m} = \frac{\dot{J}_s}{J_s} = -\frac{\dot{f}}{f} \quad (19)$$

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. Arbitrage in the capital market then implies

$$R = \frac{\pi_v}{J_v} - \frac{\dot{v}}{v} - \delta \quad (20)$$

and

$$R = \frac{\pi_j^e}{J_j} - \frac{\dot{f}}{f} - \delta, \quad j = m, s \quad (21)$$

where \dot{v}/v and \dot{f}/f represent the growth rates of the stocks of blueprints in the case of vertical integration and outsourcing respectively. These results give

$$R + \delta = \frac{v\pi_v}{k_v} - \frac{\dot{v}}{v} = \frac{f\pi_s^e}{k_s} - \frac{\dot{f}}{f} = \frac{f\pi_m^e}{k_m} - \frac{\dot{f}}{f}, \quad (22)$$

which pins down the interest rate in the Euler equation (2).

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 $L = L_v^I + L_s^I + L_m^I + v\lambda x_v + f x_m$. By (7), (12), (17) and (18), the condition can be rewritten as

$$L = k_v \left(\frac{\dot{v}}{v} + \delta \right) + k_s \frac{\dot{s}}{f} + k_m \frac{\dot{m}}{f} + v\lambda A \left(\frac{\alpha}{\lambda} \right)^{\frac{1}{1-\alpha}} + f A (\alpha\omega)^{\frac{1}{1-\alpha}}. \quad (23)$$

3.3 Organization

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 (22) held at the same time. This is generally impossible. To see this, proceed in two steps. First consider that new outsourcing agreements are signed only if there is new creation of both intermediate supplier and final assembler blueprints, which requires

$$\frac{f\pi_m^e}{k_m} = \frac{f\pi_s^e}{k_s}.$$

Using (14) and (15), this yields a fixed ratio of intermediate suppliers over final assemblers

$$r = \bar{r} \equiv \frac{k_s}{k_m} \frac{(1-\alpha)\omega}{1-\omega}. \quad (24)$$

This implies that the two types of specialized blueprints have to be invented in fixed proportions.

Turning to the second step, a case with only vertically integrated firms reflects Grossman and Helpman (1991), as the model has no transitory dynamics and jumps instantaneously to its balanced

growth path. Simple inspection reveals that, by analogy, the same property applies when only specialized firms or all types of firms are simultaneously active. Along the balanced growth path all variables either grow at the same rate or do not grow at all. Therefore, for both vertical and specialized blueprints to be generated at the same time, $\dot{f}/f = \dot{v}/v = g$ must hold. Under this constraint, $v = v_0 e^{gt}$ and $f = f_0 e^{gt}$ always hold. Then, substituting $J_v = k_v/v$ and $J_j = k_j/f$ for $j = m, s$ into (20) and (21) gives

$$\frac{\pi_v v_0 e^{gt}}{k_v} = \frac{\pi_j^e f_0 e^{gt}}{k_j}, \quad j = m, s$$

which implies

$$\frac{(1 - \alpha) \lambda^{-\frac{\alpha}{1-\alpha}} v_0}{k_v} = \frac{\eta(\bar{r}) (1 - \omega) \omega^{\frac{\alpha}{1-\alpha}} f_0}{k_s} \quad (25)$$

where \bar{r} is the bundling parameter defined in (24). Both its sides being constant, (25) is satisfied only for a zero-measure set of parameter values. Therefore, in general, specialized and vertically integrated blueprints are not invented together in equilibrium. In particular, only the former are created when

$$\lambda > \tilde{\lambda} \equiv \frac{1}{\omega} \left[\frac{k_s}{k_v} \frac{v_0}{f_0} \frac{(1 - \alpha)}{(1 - \omega)} \frac{1}{\eta(\bar{r})} \right]^{\frac{1-\alpha}{\alpha}} \quad (26)$$

and only the latter when the reverse is true. Hence, we have:

Proposition 1 *Firms choose outsourcing rather than vertical integration if and only if $\lambda > \tilde{\lambda}$.*

Higher initial experience in vertically integrated (v_0) or in specialized processes (f_0) makes new blueprints of the same type less costly to invent. Outsourcing is hence selected when there is relatively higher initial experience in outsourcing (small v_0/f_0); when specialized final assemblers have a high chance of finding specialized intermediate suppliers (high $\eta(\bar{r})$); when product differentiation is weak so that the profit share of revenues of vertically integrated firms is small (small $1 - \alpha$) relative to the share appropriated by final assemblers through bargaining (large $1 - \omega$); when vertical revenues are relatively low due to large gains from specialization (large λ) and little intermediate underproduction is caused due to sufficient supplier bargaining power (large ω); and when the blueprints for specialized assembly are relatively cheap compared with those for vertically integrated production (small k_s/k_v).

The matching probability of specialized assemblers itself depends on the relative R&D costs (k_s/k_m), the relative profit margin of final assemblers and intermediate suppliers ($(1 - \alpha)/(1 - \omega)$), and the supplier bargaining power (ω). When assemblers' R&D costs are relatively large, profit margin relatively small, and supplier bargaining power strong, the minority of entrants are final assemblers, so they are surely matched ($\eta(\bar{r}) = 1$). In this case, their matching probability is unaffected by marginal parameter changes. Here, stronger supplier bargaining power has two opposite effects: it promotes intermediate production but at the same time discourages final production. While the first effect fosters outsourcing, the second hampers it. Higher product differentiation (small α) reinforces the second effect because it makes demand more elastic, hence more sensitive to small price differences. High intermediate prices due to a large ω thus map into small final quantities sold. The best scenario for outsourcing strikes the optimal balance between those two effects, which occurs at $\omega = \alpha$. When assemblers' R&D costs are relatively small, their profit margin relatively large, and supplier bargaining power weak, the majority of entrants are final assemblers reducing their chances of being matched ($\eta(\bar{r}) < 1$). In this situation, the impact of ω on the propensity to outsource becomes unambiguously positive. The reason is that, by fostering intermediate entry and hampering final entry, stronger supplier bargaining power (larger ω) raises the matching probability of final assemblers.

4 Growth

4.1 Vertical Integration

When condition (26) does not hold, no labor is allocated to specialized innovation ($L_s^I = L_m^I = 0$), so no new specialized patent is ever created: $\dot{s} = \dot{m} = 0$ and asymptotically $f = 0$. Along a balance growth path, we have $\dot{v}/v = g_v$ and $\dot{E} = 0$. This allows us to write the full employment condition (23) and the Euler condition (2) as:

$$L = k_v (g_v + \delta) + \alpha E$$

and

$$0 = \frac{(1 - \alpha) E}{k_v} - g_v - \rho - \delta.$$

These can be solved to yield the equilibrium values of expenditures and growth:

$$E_v^G = L + \rho k_v, g_v^G = (1 - \alpha) \frac{L}{k_v} - \alpha \rho - \delta. \quad (27)$$

Under vertical integration growth is boosted by weak time preference (small ρ), slow depreciation (small δ), large size of the economy (large L), small R&D cost (small k_v), and pronounced product differentiation (small α). While a large size of the economy also gives large expenditures, weak time preference and small R&D costs depress them. A high rate of depreciation hence lowers both growth and expenditure by reducing the incentive to innovate and diverting labor from alternative uses. Differently, stronger time preference (larger ρ) has a negative impact on the growth rate but a positive one on expenditures since it biases intertemporal decisions towards consumption and away from saving. Finally, higher costs of innovation (larger k_v) increases expenditures and have a negative impact on growth whereas a larger economy (larger L) supports proportionately larger expenditures accompanied by higher economic growth.

4.2 Outsourcing

When condition (26) holds, no labor is allocated to vertical innovation ($L_v^I = 0$), so no vertically integrated blueprints are ever created: $\dot{v} = 0$ and asymptotically $v = 0$. Along a balanced growth path, we have $\dot{f}/f = g_f$ and $\dot{E} = 0$. This allows us to write the long run full employment condition (23) and the Euler condition (2) as:

$$L = \frac{k_s + k_m \bar{r}}{\eta(\bar{r})} (g_f + \delta) + \alpha \omega E$$

and

$$0 = \frac{\eta(\bar{r}) (1 - \omega) E}{k_s} - g_f - \rho - \delta.$$

Given the definition of \bar{r} in (24), these can be solved together to yield

$$E_f^G = L + \rho \frac{k_s}{\eta(\bar{r})} \frac{1 - \omega \alpha}{1 - \omega}, g_f^G = \eta(\bar{r}) (1 - \omega) \frac{L}{k_s} - \rho \omega \alpha - \delta, \quad (28)$$

which depend on the matching probability of assembler entrants $\eta(\bar{r})$. Hence, there are two cases. If there are fewer assemblers than intermediate entrants ($\bar{r} > 1$), then the former are surely matched, so $\eta(\bar{r}) = 1$. Accordingly, (28) becomes:

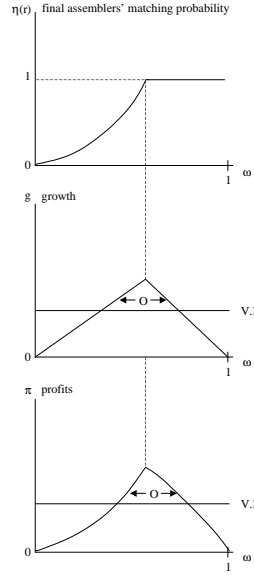
$$E_s^G = L + \rho k_s \frac{1 - \omega\alpha}{1 - \omega}, g_s^G = (1 - \omega) \frac{L}{k_s} - \rho\omega\alpha - \delta. \quad (29)$$

If there are more assembler than intermediate entrants ($\bar{r} < 1$), then the latter are surely matched, so $\eta(\bar{r})/\bar{r} = 1$. This allows us to write (28) as:

$$E_m^G = L + \rho k_m \frac{1 - \omega\alpha}{(1 - \alpha)\omega}, g_m^G = (1 - \alpha)\omega \frac{L}{k_m} - \rho\omega\alpha - \delta. \quad (30)$$

As under vertical integration, in both cases growth is fostered by weak time preference (small ρ), slow depreciation (small δ), large size of the economy (large L), small R&D cost (small k_s or k_m), and pronounced product differentiation (small α). A large size of the economy also supports large expenditures whereas weak time preference as well as small R&D costs depress them. The impact of product differentiation on expenditure is different under the two matching cases. The reason is that the annuity value of the initial stock of blueprints depends positively on the dividends to assembler patents and negatively on the matching probability of new assembler entrants. When matching is certain ($\bar{r} > 1$), little differentiation (large α) depresses dividends and thus expenditures. When matching is uncertain ($\bar{r} < 1$), little differentiation depresses the matching probability more than the dividends, which sustains expenditures. Finally, when assemblers are uncertain about finding a partner, higher supplier bargaining power (larger ω) increases assemblers' matching probability by encouraging supplier entry. This reduces expenditures and promotes growth ($dg_m/d\omega > 0$ provided that $g_m > 0$). On the other hand, when assemblers are surely matched ($\bar{r} > 1$) a larger ω is associated with larger expenditures and slower growth. This is because the matching probability no longer plays a role, while the return to assembly falls, thus discouraging the creation of new assembler blueprints.

Figure 2: Intermediate Supplier Bargaining Power



4.3 Bargaining and growth

We now analyze the role of the bargaining weight ω on our results. Particularly, we highlight a direct link between growth and the proportion of suppliers over assemblers that enter the market, \bar{r} , which is in turn determined by the bargaining weight granted to each side. The top panel of Figure 2 displays the matching probability of final assemblers as a function of ω . It shows that a higher ω encourages supplier entry thereby raising assembler matching probability until there is an equal number of the two types of entrants. A higher number of suppliers thereafter only reduces their own matching probability, while leaving the assemblers' unchanged.

The middle panel of Figure 2 shows the impact of ω on growth. The flat line represents the growth rate under vertical integration, which shows that outsourcing yields faster growth than vertical integration when the bargaining weight of suppliers takes intermediate values. In particular, the supplier weight that yields the maximum rate of growth is the critical ω that just sets \bar{r} in (24) equal to one:

$$\omega^* = \frac{k_m}{k_s(1 - \alpha) + k_m}. \quad (31)$$

For $\omega = \omega^*$, the same number of suppliers and assemblers enter the market ($\dot{m} = \dot{s}$), so search costs are minimized as both groups are certain of being matched. In other words, in the search process

the negative intra-group externalities exactly offset the positive inter-group externalities. For higher $\omega > \omega^*$, we have $\bar{r} > 1$ and thus $\eta(\bar{r}) = 1$. Accordingly, a higher bargaining weight has no impact on the matching probability of final assemblers leaving only a negative effect on their returns, their incentives to enter and growth. The critical value ω^* is increasing in α and decreasing in k_s/k_m : a larger bargaining weight of suppliers is needed to compensate the stronger incentive to enter final assemblers have when product differentiation rises and their relative entry costs fall.

The bottom panel in Figure 2 compares the profitability of vertical integration with that of outsourcing showing that the latter is preferred by firms in the region of ω such that the number of supplier and assembler entrants are similar. This suggests that outsourcing tends to take place in situations where it promotes economic growth. Nonetheless, the overlap is not complete. Recall from inequality (26) that all firms choose to outsource if λ is sufficiently high. On the other hand, (27), (29) and (30) reveal that whether outsourcing promotes faster growth than vertical integration is independent from λ . The reason is that, once all firms have chosen to vertically integrate or outsource, λ no longer enters their profits, as they all enjoy the same market share (E/v or E/f respectively). This creates circumstances under which all firms outsource when vertical integration would lead to faster growth. Specifically, using (27), (29) and (30) to set $g_v^G = g_s^G$ and $g_v^G = g_m^G$, we can determine the range of ω in which outsourcing brings faster growth. The upper and lower bounds of this range are

$$\tilde{\omega}_s = 1 - \frac{k_s}{k_v} \frac{L(1-\alpha)}{L + \alpha\rho k_s} \text{ and } \hat{\omega}_m = \frac{k_m}{k_v} \frac{L(1-\alpha) - \alpha\rho k_v}{L(1-\alpha) - \alpha\rho k_m}.$$

They correspond to the two scenarios of $\eta(\bar{r}) = 1$ and $\eta(\bar{r}) < 1$ respectively and can be ranked $\tilde{\omega}_s > \hat{\omega}_m$ under the assumption $k_v > k_s + k_m$. The range $[\hat{\omega}_m, \tilde{\omega}_s]$ in which outsourcing brings faster growth is wider the higher the relative R&D cost advantage for specialized blueprints with respect to vertically integrated ones (the smaller k_s/k_v and k_m/k_v). We can then write:

Proposition 2 *Firms choose outsourcing rather than vertical integration and their decision leads to faster growth if and only if $\lambda > \tilde{\lambda}$ and $\hat{\omega}_m < \omega < \tilde{\omega}_s$.*

If $\lambda > \tilde{\lambda}$ and $\omega < \hat{\omega}_m$ or $\omega > \tilde{\omega}_s$, firms choose outsourcing when vertical integration maximizes

growth. If $\lambda < \tilde{\lambda}$ and $\hat{\omega}_m < \omega < \tilde{\omega}_s$, firms choose vertical integration when outsourcing maximizes growth. If $\lambda < \tilde{\lambda}$ and $\omega < \hat{\omega}_m$ or $\omega > \tilde{\omega}_s$, firms choose vertical integration and this promotes faster growth.

5 Welfare

In the previous section we have highlighted a possible tension between the reduction of production costs through adequate organizational choices and the implied rate of growth through innovation. We now assess the implications of that tension from a welfare point of view.

In so doing, we consider the point of view of a benevolent planner who can choose firms' organizational modes but cannot deal directly with the distortions due to firm market power and intertemporal externalities in R&D. Since our model has no transitional dynamics, we can focus on a situation in which expenditures are constant at level E_q^G , prices are constant at p_q and the stock of patents grows at the constant rate g_q^G starting from some initial level q_0 , for $q = v, f$. Our welfare indicator is the present discounted value of current and future instantaneous utility flows. Given (1), that is equal to

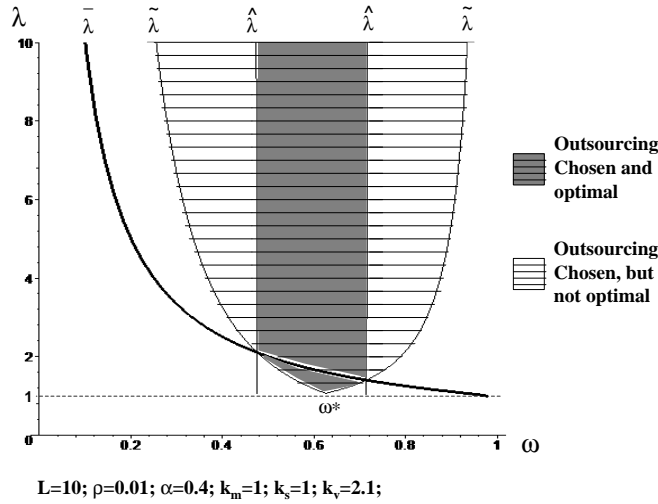
$$W_q = \frac{1}{\rho} \left(\ln E_q^G - \ln p_q + \frac{1-\alpha}{\alpha} \ln q_0 \right) + \frac{1}{\rho^2} \left(\frac{1-\alpha}{\alpha} g_q^G \right) \quad (32)$$

The two terms of the right hand side denote the 'static' and the 'dynamic' components of welfare respectively. Changes in the former represent the gains/losses in consumption brought about by changing expenditures and prices. Changes in the latter measure the gains/losses due to changing the growth rate. Welfare for each industry equilibrium can be derived by substituting the appropriate values of prices, expenditures and growth rates from (8), (13), (27) and (28).

In comparing vertical integration and outsourcing, we assume that $v_0 = f_0$ to abstract from trivial differences due to the initial numbers of blueprints. We can then write the threshold λ above which outsourcing results in higher consumption as

$$\bar{\lambda} \equiv \frac{(1-\omega)\eta(\bar{r})(L + \rho k_v)}{\omega[L\eta(\bar{r})(1-\omega) + \rho k_s(1-\omega\alpha)]}, \quad (33)$$

Figure 3: Static and Dynamic Welfare Implications of Outsourcing



and the threshold λ above which outsourcing results in higher overall welfare (32) as

$$\hat{\lambda} \equiv \bar{\lambda} e^{\frac{1}{\rho} \frac{1-\alpha}{\alpha} (g_v^G - g_f^G)}. \quad (34)$$

Definition (34) clearly shows that the welfare implications of firm organization are a combination of static and dynamic gains and losses. We can thus write:

Proposition 3 *Outsourcing dominates vertical integration in welfare terms if and only if $\lambda > \hat{\lambda}$.*

We are now ready to compare the threshold $\tilde{\lambda}$ in (26), above which outsourcing is the equilibrium organizational form, with threshold $\hat{\lambda}$ in (34), above which outsourcing is the dominant organizational form from a welfare point of view. This is done in Figure 3, which depicts $\tilde{\lambda}$ and $\hat{\lambda}$ together with $\bar{\lambda}$ as functions of the bargaining weight ω .

Outsourcing is preferred from a static welfare point of view in the entire region that lies to the right of $\bar{\lambda}$. The patterned area represents parameter values for which firms actually engage in outsourcing in equilibrium. In the dark shaded area, outsourcing is also the preferred outcome from an overall welfare point of view. Finally, the white patterned area shows the region where firms choose outsourcing, but in so doing generate slower growth and hence lower welfare than vertical integration. Figure 3 shows that outsourcing is chosen by firms and brings higher welfare when there are substantial gains from specialization (large λ) and the ex post bargaining weights

of intermediate suppliers and final producers tend to mirror the relative incentives of labs to create the corresponding blueprints (ω close to ω^*). When this is the case, search and hold-up frictions are minimized. Thus, by (31), *in sectors in which the R&D costs of intermediate blueprints are large (resp. small) with respect to the R&D cost of final blueprints, outsourcing is likely to be welfare improving only when the bargaining weight of intermediate suppliers is also large (resp. small) with respect to the bargaining weight of final assemblers.* These results are amplified in sectors with pronounced product differentiation.

6 Conclusion

We have proposed an endogenous growth model with outsourcing to explore the implications of fragmented production for innovation and growth. The model has revealed a tension between the static and dynamic effects of outsourcing stemming from the fact that producers neglect the impact of their organizational choices on innovation when this is performed by independent labs. For this reason, when outsourcing is selected, the corresponding static gains from specialized production may at times be associated with relevant dynamic losses for consumers due to slower innovation. Whether this happens or not depends on sector characteristics. In particular, we have shown that in sectors in which the R&D costs of intermediate blueprints are large (resp. small) with respect to the R&D cost of final blueprints, outsourcing is likely to be welfare improving only when the bargaining weight of intermediate suppliers is also large (resp. small) with respect to the bargaining weight of final assemblers. The more so the more differentiated products are.

References

- [1] Acemoglu D., P. Aghion and F. Zilibotti (2006) Distance to Frontier, Selection, and Economic Growth, *Journal of European Economic Association* 4, 37-74.
- [2] Antras P. (2003) Firms, Contracts, and Trade Structure, *Quarterly Journal of Economics* 118, 1375-1418.

- [3] Engardio P. and B. Einhorn (2005) Outsourcing Innovation, *Business Week*, March 21.
- [4] Feenstra R. (1998) Integration of Trade and Disintegration of Production in the Global Economy, *Journal of Economic Perspectives* 12, 31–50.
- [5] Feenstra R. and G. Hanson (2004) Ownership and Control in Outsourcing to China: Estimating the Property-Rights Theory of the Firm, NBER Working Paper n.10198.
- [6] 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.
- [7] Grossman G. and E. Helpman (1991) *Innovation and Growth in the Global Economy* (Cambridge MA: MIT Press).
- [8] Grossman G. and E. Helpman (2002) Integration vs. Outsourcing in Industry Equilibrium, *Quarterly Journal of Economics* 117, 85–120.
- [9] Grossman G. and E. Helpman (2003) Outsourcing versus FDI in Industry Equilibrium, *Journal of European Economic Association* 1, 317–327.
- [10] Hart O. and J. Moore (1990) Property Rights and the Nature of the Firm, *Journal of Political Economy* 98, 1119-1158.
- [11] Helpman E. (2006) Trade, FDI, and the Organization of Firms, NBER Working Paper n. 12091.
- [12] Jones, C. (1995) R&D-Based Models of Economic Growth, *Journal of Political Economy* 103, 759-784.
- [13] Lai E., R. Riezman and P.Wang (2005) Outsourcing of Innovation, University of Iowa, mimeo.
- [14] McLaren J. (2000) Globalisation and Vertical Structure, *American Economic Review* 90, 1239-1254.
- [15] Marin D. and T. Verdier (2003) Globalization and the ‘New Enterprise’, *Journal of the European Economic Association* 1, 337-344.

- [16] Naghavi A. and G. Ottaviano (2006) Outsourcing and Industry Dynamics with Heterogeneous Firms, Universita di Bologna, mimeo.
- [17] Tomlinson M. (1999) Co-operative Competition: Innovation, Networks and Collaboration in the Computer Industry, CRIC, mimeo.
- [18] WALL STREET JOURNAL (1969) IBM's 'Unbundling' Move Makes It Target of Growing Criticism by Computer Makers, July 24.