Outsourcing, Complementary Innovations and Growth*

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Abstract

This paper studies the parallel creation of complementary innovations serving the upstream and downstream stages of a production chain with the aim of shedding light on the impact of outsourcing on R&D when supply contracts are incomplete. We argue that outsourced upstream production contributes to the emergence of innovation networks by creating a demand for upstream R&D. The bargaining weight of the two parties determines whether outsourcing decisions that lead to static specialization gains also generate dynamic gains when compared to vertically integrated production that relies on integrated R&D. In particular, growth is maximized when the bargaining power is split in a way that search and hold-up frictions are minimized. Putting this result next to the decision of firms to outsource, we conclude that complementary innovations are more likely to foster growth in Schumpeterian Mark I sectors, while vertical integration does so in Schumpeterian Mark II sectors.

Keywords: outsourcing, complementary innovations, incomplete contracts, organization of firms, Schumpeterian Mark I and II sectors.

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1 Introduction

There has been a global trend towards vertical disaggregation of manufacturing over the past three decades, with firms increasingly relying on suppliers for design and component inputs in a variety of industries (Feenstra, 1998; Womack, Jones, and Roos 1990; McKendrick, Doner, and Haggard 2000). The fragmentation of production is the most recent form of division of labor used as a business strategy to exploit gains from specialization. The decision to outsource is often driven by the need to reduce costs, save time, and enhance flexibility. This allows firms to concentrate on activities in which they benefit from some competitive advantage. Given the complexities of today's technologies and supplier chains, outsourcing is no longer a concept limited to manufacturing and services (Sabel 1994, Helper, McDuffie, and Sabel 2000). Today, subcontractors are involved in design issues, doing critical R&D, and have become central in efforts to improve quality. The key to sustain competitive advantage in the global market tends to increasingly hinge on the utilization of creativity and skills of specialized workers and engineers around the world. In particular, single firms in industries experiencing a rapid development of technological progress and knowledge distribution no longer possess the necessary skills to produce significant innovations in all areas of progress (Powel and Brantley 1992, Powell, Koput, and Smith-Doerr 1996, Hagedoorn and Duysters 2002). Such circumstances have led to the rise of networks as the locus of innovation to create the crucial specialized knowledge necessary to improve firms' competitive position. Outsourcing has created a market for complementary innovations giving rise to a complex network of innovators, i.e. 'global innovation networks'. This has been possible through a simple division of labor, which in turn has instigated a division of knowledge creation.

The model of networks of innovators has indeed become common practice (Powell 1990; Rosenbloom and Spencer 1996; Roberts and Liu 2001; Chesbrough 2003) with interorganizational partnerships now serving as a core component of corporate strategy (Gomes-Cassares 1996; Hagedoorn 1996; Noteboom 1999; Ahuja 2000). Such networks take various forms according to their temporal stability and forms of governance and have been classified into four key types: informal networks, project networks, regional networks, and business networks. Within these groups, project networks, which are short-term links to accomplish specific tasks, are categorized under formal networks, and are most likely to give rise to contractual issues as trust, stability and relational continuity do not enter into the picture. Outsourcing contracts in a supply chain network governed by a 'lead' firm are a common example of such networks.

Against this background, this paper addresses the question whether the success of project networks can be taken for granted in all sectors and under all circumstances. There are good reasons to suspect that may not be the case as the role of innovation in determining growth, performance, and hence industrial dynamics differs greatly across sectors. The traditional approach of industrial economics focuses on R&D intensity and market structure as key indicators to distinguish sectors. A rich tradition of sectoral studies has shown that sectors also differ in terms of the knowledge base, the relevant institutions, and the role of and the relationship among actors involved in innovation. As a result, market structure and industrial dynamics have been used to classify sectors in two main categories. The first category, called *Schumpeterian Mark I*, is dominated by 'creative destruction' driven by technological ease of entry as well as by a major role played by entrepreneurs and new firms in innovative activities. The second category, called *Schumpeterian Mark II*, is dominated by 'creative accumulation' driven by large established firms in the presence of relevant barriers to entry for new innovators.

The paper addresses the complex issue of the conditional success of project networks from a specific angle focusing on a special reason why innovation networks arise, namely to serve the needs of fragmented production. From this angle causation goes from the decision to outsource production to the emergence of innovation networks, which allows us to study the conditions under which the static gains driving the outsourcing choice may also be associated with dynamic gains due to faster innovation and growth.[1] In so doing, we develop a dynamic model in which fragmented production ('outsourcing') and complementary innovations ('innovation networks') may arise simultaneously due to gains from specialization. Our aim is to not only explain how sectoral differences contribute to organizational form, but also capture the dynamic growth aspects by discussing how these sectors could evolve over time. We show that complementary innovations, made possible through outsourcing decisions, are more likely to foster growth in Schumpeterian Mark I sectors, while vertical integration does so in Schumpeterian Mark II sectors.

Our results help shed light on a variety of empirical findings that are consistent with the idea that the optimal form of organization can vary according to the characteristics of sectors. Most empirical studies of the relationship between networks and innovation focus on formal ties established among organizations. This stream of research documents a strong positive relationship between outsourcing and innovation, across such diverse industries as chemicals (Ahuja 2000), biotechnology (Powell et al. 1996, 1999; Walker, Kogut, and Shan 1997; Baum, Calabrese, and Silverman 2000), telecommunications (Godoe 2000), and semiconductors (Stuart 1998, 2000). On the other hand, the inspection of a number of key sectors (such as chemicals, computers, semiconductors, and software) reveal that the role of outsourcing in stimulating innovation varies case by case and changes over time. In the chemical sector, large integrated firms have been the major source of innovation over a long period of time, enjoying major innovative advantages due to large R&D expenditure, economies of scale and scope, and cumulativeness of technological advance (Chandler 1990; Arora, et al. 1998). However, major changes related to the development of chemical engineering and the concept of unit operation have led to an increasing division of labor between chemical companies and technology suppliers, giving rise to the

[1] The literature on innovation networks and sectoral systems suggests that causation may also run in the opposite direction as the complexity of the R&D activities in some industries tends to increase the need for the formation of innovation networks and outsourcing. See, for instance, Freeman (1991) and Hagedoorn (1995).

formation of specialized engineering firms vertically linked to those companies. Also the computer sector has always been dominated by large firms, with high cumulativeness of technological advance. In the 60s and the 70s mainframes were produced by vertically integrated firms, and IBM was the typical example producing both components and systems conducting activities in development, manufacturing, marketing, and distribution of large systems and their key components. When mini- and micro-computers were introduced, the computer sector experienced the entry and growth of firms specialized either in components or in systems. Competition became characterized by groups of specialized firms, and innovation became decentralized. Meanwhile, the semiconductor industry has been characterized by new entrants and specialized producers in the US, but large vertically integrated producers in Japan and Europe (Malerba 1985; Langlois and Steinmueller 1999). Finally, specialization has been crucial in the software industry, where the changing knowledge base has created an evolving division of labor among the various actors (Bresnahan and Greenstein 1998).

The rest of the paper is organized as follows. Section 2 describes the logic of our analytical framework and its relations to the existing literature. Section 3 provides a formal presentation of the resulting theoretical model of industrial organization and endogenous growth through expanding product variety. Section 4 investigates the equilibrium of the model. Section 5 discusses the consequences of firms' organizational choices on the speed of innovation at the industry level. Section 5 concludes.

2 Firm organization and endogenous growth

In order to study the interaction between firm organization and innovation, we propose an analytical framework that combines some key features of two well-established approaches to the study of economic growth on the one side, and the boundaries of the firm on the other.

In terms of growth, as in Grossman and Helpman (1991), we analyze a situation in which firms enter the market by buying the blueprints of horizontally differentiated products developed by independent labs. These are perfectly competitive and finance their R&D activities in a perfect capital market. While blueprints are protected by infinitely lived patents, technological knowledge is not fully appropriable giving rise to learning externalities that reduce the cost of R&D as experience in production cumulates through time. Differently from the dynamic model of Grossman and Helpman (1991) but in the wake of the static model of Grossman and Helpman (2002), production processes come in two types: vertically integrated and fragmented ('outsourcing'). These processes are split in two stages: upstream intermediate production and downstream final assembly. Integrated production as well as each stage of fragmented production require their own blueprints. Hence, firms enter the market as vertically integrated firms, intermediate suppliers and final assemblers by buying the corresponding blueprints. There are no economies of scope in innovation, so upstream and downstream blueprints are created independently. There are, however, gains from specialization in terms of production as fragmentation is more efficient than integration. While integrated production processes are less efficient, they are, nonetheless, ready to run without additional burdens for the firms acquiring the corresponding blueprints. Fragmented processes face, instead, searching and matching frictions between intermediate suppliers and final assemblers as well as customization costs. The three types of blueprints also face different technological opportunities (as captured by relative R&D costs), which therefore play an important role in determining firms' organizational choices as in Malerba and Orsenigo (1996,1997).

Fragmented processes also incur contractual frictions as additional relation specific investments are required in order to make matched upstream and downstream blueprints perfectly compatible with each other. The underlying idea is that full compatibility between upstream and downstream blueprints requires reciprocal customization, which firms are willing to incur only after being matched. As in Grossman and Helpman (2002), we make the realistic assumption that contracts are incomplete due to the lack of ex-post verifiability of the quality of deliverables by third parties, which implies that relation specific investments give rise to hold-up problems. Thus, our model incorporates what Grossman and Helpman (2005, p.136) "consider to be the three essential features of a modern outsourcing strategy. First, firms must search for partners with the expertise that allows them to perform the particular activities that are required. Second, they must convince the potential suppliers to customize products for their own specific needs. Finally, they must induce the necessary relationship-specific investments in an environment with incomplete contracting".

The core result of the present paper is that, albeit demonstrating a channel through which the outsourcing of production may breed innovation, our model reveals a tension between the static and dynamic implications of outsourcing that prevents this from always being the case. The reason is that the production decision is made weighting the higher searching and contracting costs of outsourcing against the missed specialization gains of vertical integration. In so doing, it does not take into full account its effects on the incentives to innovate. As a result, the static gains from specialized production may sometimes be associated with a slow down of innovation and growth. In particular, outsourcing is chosen and accelerates growth when there are substantial gains from specialization and the bargaining power of intermediate suppliers and final producers reflect the relative incentives of labs to create the corresponding blueprints. When this is the case, search and hold-up frictions are minimized. Thus, when specialized intermediate suppliers have a larger role in innovation than final assemblers, a higher supplier bargaining power in an outsourcing relation induces growth.[2] Examples of such sectors can be found in Scherer (1982),

[2] These results would still qualitatively hold if we abstracted from hold-up problems by assuming complete contracts. Nevertheless, we prefer to propose an analytical framework exhibiting all the three essential features of a modern outsourcing strategy highlighted by Grossman and Helpman (2005).

who identifies sectors that in the US are net sources of R&D for other sectors (computers, instruments), and sectors that are net users of technology (textiles, metallurgy).

There are a few existing contributions that are strictly related to this paper from a methodological point of view. The way we approach the choice on whether to fragment production or not follows recent research that investigates outsourcing in an industry equilibrium when contracts are incomplete. The main contributions of this literature are surveyed by Helpman (2006).[3] 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 (2005) for an open economy. Our focus on the dynamic effects of outsourcing is reminiscent of Glass and Saggi (2001) who develop a North-South quality ladder model of innovation in which production follows a value chain consisting of an upstream basic stage and a downstream advanced stage. They show that, by lowering production costs, outsourcing the basic stage from high-cost North to low-cost South boosts profits and therefore innovation. They do not deal, however, with matching and contractual frictions, which in our framework generate an ambiguous relation between outsourcing and innovation. Similarly, complementary innovation and matching frictions appear neither in the North-South quality ladder model with incomplete contracts by Ottaviano (2008) nor in the offshoring model with expanding product variety by Naghavi and Ottaviano (2009).[4] They do appear in Naghavi and Ottaviano (2008) who nonetheless disregard the impact of outsourcing on innovation and growth in the long run, which is the main focus of the present paper.[5]

3 The Model

3.1 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

[3] See Markusen (2002) as well as Barba Navaretti and Venables (2004) for a broader view of the theory of multinationals.

[4] Ottaviano (2008) considers the choice between insourcing and outsourcing R&D within a theoretical framework in which trade patterns and growth rates are jointly determined by international differences in the enforcement of intellectual property rights that affect firms' organizational decisions. In his framework, the quality of enforcement drives the outsourcing decision, which affects R&D returns, research intensity and growth.

[5] Lai, Riezman and Wang (2009) 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 (2006) 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.

assumed to be CES with unit elasticity of intertemporal substitution:

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

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 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:

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

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 $C(t)$:

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

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

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

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

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

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

3.2 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. As in Grossman and Helpman (1991), 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 ('innovation network'): 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.[6] 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 suppliers 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.[7] 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.

3.3 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 customized

[6] To avoid a proliferation of insightless subcases, we assume that vertically integrated firms cannot buy inputs from specialized suppliers.

[7] The 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). This would turn our setup into a quasi-endogenous growth model in the wake of Segerstrom (1998).

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.[8]

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: $f\left(\dot{s}, \dot{m}\right) = \min(\dot{s}, \dot{m})$. 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 $\eta\left(r\right) \equiv f\left(\dot{s}, \dot{m}\right)/\dot{s}$ and $\eta\left(r\right)/r$ respectively. The blueprints that correspond to unmatched entrants are instantaneously destroyed.[9]

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. This parameter will determine the share of final revenues accruing to the intermediate input producer in equilibrium and is exogenous to our model. It is an industry characteristic, which typically corresponds to the importance of relationship-specific investments, i.e. contract intensity, across industries. In this case, it would identify the market thickness of upstream intermediate inputs as it will be made clear in equation (24), and in turn, the scope for the hold-up problem in an industry.[10] We will use its comparative statics to highlight the problems that fragmented production may raise for growth by making the relative benefits of producing the intermediate input and the final output an outcome of bargaining not necessarily related to the marginal costs of upstream and downstream innovation. In particular, we will see in section 5.3 how the bargaining power interacts contemporaneously with search frictions, the growth rate, and the decision of firms to outsource.[11]

[8] This 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.

[9] This assumption is made for analytical convenience. The survival of unmatched blueprints would increase the number of statuses through which blueprints can transit without adding much insight.

[10] See Table II in Nunn (2007) for a list of the twenty least and the twenty most contract intensive industries measured according to the thickness of the upstream intermediate input market.

[11] It is not obvious how to endogenize ω as testified by the fact that it has been traditionally taken as given by the related contributions surveyed in Section 2. Empirically its relative value across industries could also be inferred by comparing their propensities to outsource after controlling for all other observable sectoral characteristics in light of condition (26).

3.4 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 customized 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.

4 Industry Equilibrium

In equilibrium the prices of goods and assets are such that households maximize utility, firms maximize profits and all real and financial markets clear. As we will discuss below, the model has no transitory dynamics and it jumps instantaneously to a steady state characterized by a balanced growth path along which all variables either grow at the same rate or do not grow at all.

4.1 Production

At time t the 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

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

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

$$\pi_s = (1-\omega) p_s y_s, \tag{10}$$

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

$$\pi_m = \omega p_s y_s - x_m, \tag{11}$$

which implies an intermediate and final output equal to

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

with associated final price

$$p_s = \frac{1}{\alpha\omega}. \tag{13}$$

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

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

and

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

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

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

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.

4.2 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

$$\dot{v} = \frac{vL_v^I}{k_v} - \delta v \tag{17}$$

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

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

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

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

Labs pay their researchers by borrowing at the interest rate R while knowing that the resulting patents will generate instantaneous dividends equal to the subsequent expected profits of the corresponding firms. Arbitrage in the capital market then implies

$$R = \frac{\pi_v}{J_v} - \frac{\dot{v}}{v} - \delta \tag{20}$$

and

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

where $\dot{v}/v$ and $\dot{f}/f$ represent the rate at which new blueprints are innovated in the case of vertical integration and outsourcing respectively. These results give

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

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

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

4.3 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

$$r = \overline{r} \equiv \frac{k_s}{k_m}\frac{(1-\alpha)\,\omega}{1-\omega}. \tag{24}$$

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.[12] 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

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

which implies

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

where $\overline{r}$ is the bundling parameter defined in (24). Both its sides being constant, (25) is satisfied only for a zero-measure set of parameter values. In other words, the set of parameter values satisfying (25) is a negligible fraction of the overall set of all feasible parameter values. Therefore, in general, specialized and vertically integrated blueprints are not invented together in equilibrium. In particular,

[12] See Grossman and Helpman (1991) pp. 54-56. The basic argument rests on the assumption that expectations are rational and assets are priced at their fundamental level ('no bubbles'), i.e. the value of a patent equals the present discounted value of future profits. When this is the case, due to the linear R&D technology, expectations can be fulfilled only if the economy jumps immediately to the steady state. If initial beliefs entailed an outcome different from the steady state, they would remained unfulfilled. This would be inconsistent with rational expectations.

only the former are created when

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

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. The latter 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 $\eta(\overline{r})$); 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 ($\eta(\overline{r}) = 1$). 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 ($\eta(\overline{r}) < 1$). 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.

5 The Speed of Innovation

5.1 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 balanced growth path, we have $\dot{v}/v = g_v$ and $\dot{E} = 0$.[13] This allows us to write the full employment condition (23) and the Euler condition (2) as:

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

and

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

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

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

Under vertical integration innovation 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). A high rate of depreciation lowers the speed of innovation by reducing the incentive to innovate. Differently, stronger time preference (larger ρ) has a negative impact on the rate of innovation 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) increase expenditures and slow innovation whereas a larger economy (larger L) supports proportionately larger expenditures accompanied by a faster rate of innovation.

5.2 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 $v = 0$.[14] 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:

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

[13] The initial stock of specialized blueprints depreciates through time and asymptotically disappears since it is not refilled. See Naghavi and Ottaviano (2008) for details.

[14] The initial stock of vertically integrated blueprints depreciates through time and asymptotically disappears since it is not refilled. See Naghavi and Ottaviano (2008) for details.

and

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

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

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

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

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

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

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

As under vertical integration, in both cases innovation 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 ($\overline{r} > 1$), little differentiation (large α) depresses dividends and thus expenditures. When matching is uncertain ($\overline{r} < 1$), 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 innovation ($dg_m/d\omega > 0$ provided that $g_m > 0$). On the other hand, when assemblers are surely matched ($\overline{r} > 1$) a larger ω is associated with larger expenditures and slower rate of innovation. 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.

5.3 Bargaining Power

We now analyze the role of the bargaining weight ω on our results. Our purpose here is to highlight the problems that fragmented production may raise for growth by possibly making the relative benefits of producing the intermediate input and the final output independent from the relative marginal costs of upstream and downstream innovation. Particularly, we highlight a direct link between innovation 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 1 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 1 shows the impact of ω on the speed of innovation. The flat line represents the innovation rate under vertical integration, which shows that outsourcing yields a faster pace of innovation than vertical integration when the bargaining weight of suppliers takes intermediate values. In particular, the supplier weight that yields the maximum speed of innovation is the critical ω that just sets $\bar{r}$ in (24) equal to one:

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

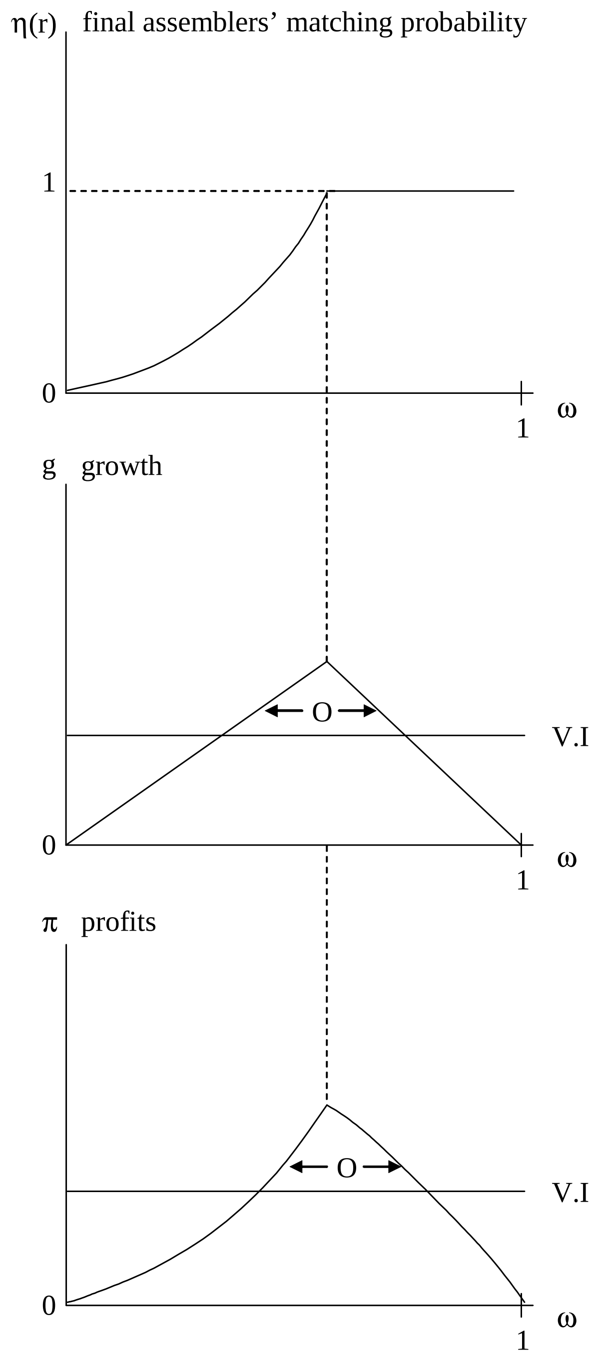
For $\omega = \omega^*$, the same number of suppliers and assemblers enter the market ($\dot{m} = \dot{s}$), so search costs are minimized as both groups are certain of being matched. For higher $\omega > \omega^*$, we have $\bar{r} > 1$ and thus $\eta(\bar{r}) = 1$. Accordingly, a higher bargaining weight has no impact on the matching probability of final assemblers leaving only a negative effect on their returns, their incentives to enter, and hence innovation. 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 1 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 accelerates innovation. 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 innovation 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 a higher speed of innovation. 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 speeds innovation. The upper and lower bounds of this range are

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

They correspond to the two scenarios of $\eta(\bar{r}) = 1$ and $\eta(\bar{r}) < 1$ respectively and can be ranked $\check{\omega}_s > \hat{\omega}_m$ as long as $k_v > L[k_s(1-\alpha)+k_m]/(L+\alpha\rho k_s)$.

Figure 1: Intermediate Supplier Bargaining Power



The range $[\hat{\omega}_m, \breve{\omega}_s]$ in which outsourcing brings faster innovation 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 accelerated innovation if and only if $\lambda > \tilde{\lambda}$ and $\hat{\omega}_m < \omega < \breve{\omega}_s$.*

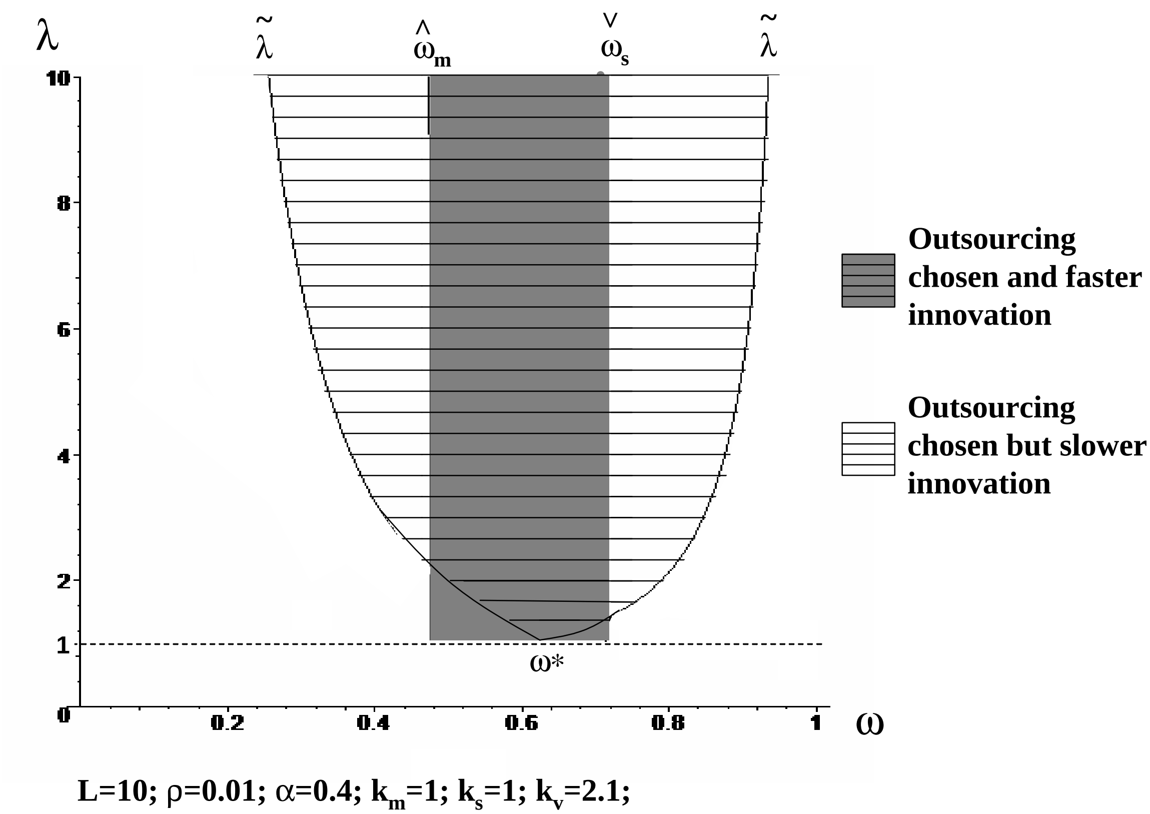
Proposition 2 tells us that outsourcing is chosen and accelerates growth in industries, where there is substantial gains from specialization, and the ex-post bargaining weights of intermediate suppliers and final producers reflect the relative incentives of labs to create the corresponding blueprints so that search and hold-up frictions are minimized. These results are amplified in sectors with pronounced product differentiation. This can be associated with Schumpeterian Mark I sectors, where specialized firms do not have large R&D entry costs relative to vertically integrated firms. Therefore, the range $[\hat{\omega}_m, \breve{\omega}_s]$ is larger. Note however that although outsourcing maximizes the speed of innovation within this range, it is possible that firms choose vertical integration when there is a lack of sufficient specialization gains, i.e. when $\lambda < \tilde{\lambda}$. If $\lambda < \tilde{\lambda}$ and $\omega < \hat{\omega}_m$ or $\omega > \breve{\omega}_s$, firms choose vertical integration and this promotes innovation. This is more likely in Schumpeterian Mark II sectors, where the range $[\hat{\omega}_m, \breve{\omega}_s]$ is small due to large costs of entry by specialized firms relative to large vertically integrated ones. If $\lambda > \tilde{\lambda}$ and $\omega < \hat{\omega}_m$ or $\omega > \breve{\omega}_s$, firms choose outsourcing due to specialization gains when vertical integration still maximizes the speed of innovation.

Proposition 3 *Outsourcing is more likely to foster growth in Schumpeterian Mark I sectors, where specialized firms have low R&D entry costs relative to integrated firms (k_s/k_v and k_m/k_v is low and thus the range $[\hat{\omega}_m, \breve{\omega}_s]$ large). In contrast, vertical integration is more likely to promote growth in Schumpeterian Mark II sectors, where the reverse is true.*

The patterned region in Figure 2 represents the combinations of λ and ω where outsourcing is chosen by firms for given parameter values. The figure then illustrates whether the organizational decisions of firms coincide with a higher speed of innovation in the economy. The shaded patterned region shows the combinations of λ and ω where firms outsource and their decision to do so accelerates the rate of innovation. On the other hand, the white patterned area shows the area where firms' decision to outsource generates slower innovation than vertical integration.

We can also conclude that outsourcing is chosen by firms and encourages innovation when the ex post bargaining weights of intermediate suppliers and final producers tend to reflect 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

Figure 2: Dynamic Effects of Outsourcing on Innovation



final blueprints, outsourcing is likely to accelerate innovation when the bargaining weight of intermediate suppliers is also large (resp. small) with respect to the bargaining weight of final assemblers.[15]

6 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 transitionary 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

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

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 variations in expenditures and prices. Differences in the latter measure the gains/losses due to a higher/lower growth rate generated by different forms of organization. Welfare for each industry equilibrium can be derived by substituting the appropriate values of prices, expenditures and growth rates.

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 use (8), (13), (27) and (28) in (32) to solve for the threshold λ above which outsourcing results in higher consumption:

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

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

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

Definition (34) clearly shows that the overall welfare implications of firm organization are a combination of static and dynamic gains and losses, namely $\bar{\lambda}$ and the sign of $(g_v^G - g_f^G)$. Regardless of static consumption gains from lower

[15] These results are amplified in sectors with pronounced product differentiation.

prices, outsourcing could result in a welfare loss in the long-run if it slows growth ($g_v^G > g_f^G$) as this makes $\hat{\lambda} > \bar{\lambda}$.[16] We can thus write:

Proposition 4 *Outsourcing can be dominated by vertical integration in terms of welfare when $g_v^G > g_f^G$ and $\bar{\lambda} < \lambda < \hat{\lambda}$ even if it creates static gains from lower prices and higher consumption.*

7 Conclusion

We have proposed a model of horizontal product innovation with outsourcing to explore the implications of fragmented production for innovation. Our model exhibits the three essential features of a modern outsourcing strategy: search for adequate partners; specific investment in mutual customization; and bilateral hold-up problems under incomplete contracting.

Focusing on situations in which the fragmentation of production leads to complementary innovations by upstream and downstream labs ('innovation networks'), we have characterized the conditions under which the organizational choices of firms in terms of production foster or hamper innovation. Our findings particularly emphasize the importance of the creation of innovation networks in Schumpeterian Mark I sectors. In other words, in sectors where there is technological ease of entry for specialized innovators in the market, the presence of networks conducting complementary innovation tends to occur and enhances growth. As mentioned in the introduction, examples of such sectors include the software industry and more recently the computer and chemical industries. This also reflects a transition from vertical integration to outsourcing due to increased specialization gains that have occurred in these sectors over the last three decades.

The analysis also highlights the importance of the revenues sharing rules between upstream and downstream producers in the course of the formation of networks for the latter to promote innovation and growth. We have shown that the long run effects of fragmented production on innovation are sector specific and depend on the structure of the market. In particular, in sectors in which the R&D costs of upstream innovations are large (resp. small) with respect to the R&D cost of downstream innovations, outsourcing is likely promote growth only when the revenue share of intermediate suppliers is also large (resp. small) with respect to that of final assemblers. As the relative benefits of intermediate and final production diverge from the costs of upstream and downstream innovation, it becomes more likely for the static gains from outsourced production to lead to dynamic losses due to slower innovation. This stems from the fact that producers partially neglect the impact of their organizational choices on innovation. Hence, although the interests of firms and labs are generally aligned, the positive link between the organization of firms and the speed of innovation cannot be taken for granted.

[16] Recall from the previous section that the different growth rates and hence the condition $g_v^G > g_f^G$ is determined by the ex-post bargaining power of the two parties.

Before concluding it is important to acknowledge some limitations of our analysis that are worth further investigation. First, in our model, innovation only occurs in disembodied form (blueprints) rather than through embodied knowledge acquisition. This contrasts with what frequently happens in fragmented production, where upstream specialized suppliers develop new machineries and precision instruments (or other advanced services) that are subsequently purchased by downstream producers. The innovative process for the latter is thus largely dependent on this. Second, the literature on innovation networks and sectoral systems suggests that the causation mechanism running from outsourcing to innovation may also run in the opposite direction. Two-way causation may then lead to a self-reinforcing virtuous circle between network development and innovation performance. Third, in our model the relative benefits of intermediate and final producers (as determined by their relative bargaining powers) are unrelated to the costs of upstream and downstream innovation. This assumption has been instrumental in order to highlight the importance of the alignment between such costs and benefits for growth. It would be interesting to understand whether and how they are actually linked in reality. Fourth, our model assumes that in each period upstream and downstream producers search for a collaborative partner to match their products. However, relational continuity and repeated interaction between partners may develop mutual trust thus mitigating the hold-up problem. Extending the model to develop this insight may shed light on the working of regional clusters and industrial districts.

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