Profiting in the Info-Coms Industry in the Age of Broadband: Lessons and New Considerations

Jackie Krafft[1]

October 5, 2006

Abstract

Who profits in the info-coms industry in the broadband age, and how? This paper looks at this question, decomposing the industry in terms of five complementary activities: (1) equipment provision, (2) network operation, (3) Internet access and service provision, (4) navigation and security provision, and (5) Internet content provision, which correspond to five different assets in the sense of Teece (1986). By focusing on two key stylized facts (SF1: "R&D and patent licensing are increasingly high in this industry, but the initiators of innovations have greatly changed over time", and SF2: "Small, facilities-less companies emerged during the development of the Internet industry, but have generally performed badly as the industry has matured and broadband use has become widespread") the paper analyses the robustness of Teece (1986) in its ability to provide a framework appropriate to the changes that have occurred in the broadband industry. The paper draws some lessons, and provides some new considerations related to the robustness of Teece's framework.

Keywords:

Innovation, Broadband, Vertical integration, Vertical specialization, Complementarity in Assets, Activities and Capabilities.

JEL Codes:

L22, L86, L96, O31

[1] CNRS-GREDEG, 250 rue Albert Einstein, 06560 Valbonne, France, Tel: 33 4 93 95 41 70, Fax: 33 4 93 65 37 98, e-mail: jkrafft@idefi.cnrs.fr; jkrafft@gredeg.cnrs.fr

1. Introduction

In 1986 David Teece published his now famous article entitled "Profiting from innovation", a work that has greatly influenced research in economic organization, business strategy, economics of technology and innovation. The key value of his article is that it provides a general theory about integration, collaboration, licensing and public policy in the presence of technological innovation. By a general theory, we mean a guide to ongoing research into the economics of the innovative firm, rather than the outcome of an intellectual process that can be assumed to apply at all times and in all places. This guide enables observation and analysis of regularities in firm and industry dynamics that are not determined contextually, and the differences that make certain corporate or industrial conjectures unique.

This paper explores whether Teece's conclusions, made 20 years ago, apply in a world where profiting from innovation essentially occurs in a global, digitally interconnected economy. One of the keys to this global, digitally interconnected economy is without doubt broadband, the late stage of development of the Internet economy. The aim of this paper is to identify, from Teecian point of view, who, in this age of broadband, profits in the info-coms industry, and how. We define the info-communications industry as comprising a set of five complementary activities: (1) equipment provision, (2) network operation, (3) Internet access and service provision, (4) navigation and security provision, and (5) Internet content provision. These complementary activities correspond to Teece's five assets: (1) R&D, (2) production of network facilities, (3) commercialization/distribution of basic Internet services, (4) commercialization/distribution of improved services, and (5) commercialization/distribution of advanced services. With the emergence of broadband, info-coms companies have developed various organizational strategies, such as specialization in one type of activity, but also have followed strategies of integration and collaboration to enable entry into a related range of activities. These organizational strategies, in practice, are not all profitable and, as Teece (1986) correctly stressed as a general principle, their success appears to depend to a great extent on whether they are initiated by innovators or imitators, and how they are articulated within a) regimes of appropriability, namely the environmental factors that govern an innovator's ability to capture the profits generated by an innovation; b) dominant design issues, i.e. whether the industry is in a phase of emergence, growth, maturity or decline; and c) complementary assets access, i.e. the ability of firms to develop or acquire

the capabilities required to coordinate the complementary assets corresponding to the development of the innovation.

The paper will focus particularly on the following set of topics that are at the core of Teece's paper. These topics are formulated in terms of two essential stylized facts (SF1 and SF2):

- SF1: R&D and patent licensing are increasingly high in this industry, but the initiators of innovations have greatly changed over time.
- SF2: Small, facilities-less companies have emerged everywhere during the development stage of the Internet industry, but have generally performed badly once the industry matured and broadband became more generally available.

We argue that analysing who profits in the broadband industry, and how, provides an opportunity to revisit Teece's article, and to draw some new angles. We reconfirm the idea that the dynamics of complementary assets are crucial to analyse how firms perform in an innovative industry along the different stages of its development life cycle. However, this needs to be complemented by two key elements. First, an analysis of the sources of technology provision, which, even in a tight appropriability regime, may stimulate the entry of firms with no complementary assets or core capabilities in related (upstream/downstream) activities, and may penalize early innovators. Second, a focus on the increasing heterogeneity of firms where facilities-based companies (firms that own their complementary network assets) compete with facilities-less firms (firms that do not own these assets). For both types of organization, speed in accessing complementary assets is crucial to avoid dramatic disequilibria, shakeout and turbulence.

In essence, Teece's seminal article emphasizes that there is a crucial problem of coordination within and between firms that is not spontaneously solved. The development of complementary assets, and especially their coordination along the process of innovation, is never guaranteed (whatever the stage of evolution of the industry and whatever the appropriability regime), especially since the capabilities needed to access these complementary assets have to be built over time. In this paper, we validate this principle: although info-coms activities are related and complementary, firms cannot always evolve from their initial activity to a new one. Capabilities are required to access the new complementary assets available, either through internal development or external cooperation on the basis of contracts or alliances.

The paper is organised as follows. In Section 2, we stress that it is possible to decompose the industry into a layered structure (Layer 1 to Layer 5), where each individual layer regroups companies involved in similar activities (based on the same capabilities), while upstream/downstream layers regroup companies involved in complementary activities (based on complementary capabilities). This decomposition is especially useful since it allows us to map how different companies locate in the different layers, based on their initial capabilities, and how they are able to evolve – move from one layer to another – through the development or acquisition of new capabilities, and access (or not) the complementary assets as defined by Teece. This decomposition also facilitates discussion of some stylized facts that are particularly significant for this industry. In Section 3, we present and analyse SF1. We stress that firms from Layer 1 (equipment suppliers) are today's essential technology providers although, a mere decade ago, Layer 2 firms (network operators) filled this role. We show that this change in the sources of technology provision has had a positive impact on the entry of new firms in Layers 1 and 2, in particular, by attracting firms that did not possess the core assets or capabilities to penetrate the industry and that, in other circumstances, should have been prevented from entering or would have exited soon after entry. Also, this process of change in the initiators of technological innovation means that the initial developers of new technologies in Layer 1 (data processing and software companies) were frequently acquired by imitators (the incumbent traditional equipment suppliers), confirming Teece's general prediction that early innovators do not necessarily win. In Section 4, we examine SF2 by focusing on firms from Layer 3 (Internet Access Providers and Internet Service Providers, the IAPs/ISPs). Our results show that these companies have contributed to the diffusion of the Internet as a technological innovation, but most failed to access the complementary assets necessary for high performance in the broadband world. Only the biggest ones, which vertically integrated into commercialization/distribution of improved and advanced services assets, such as AOL, Yahoo! and Google, have been able to survive and become key actors in the broadband economy. Section 5 concludes that 20 years on, Teece (1986) still provides a robust framework, which is especially useful to analyse who profits and how in the info-coms industry in the age of broadband.

2. The layered structure of the info-coms industry at the age of broadband

2.1. Is broadband an innovation?

Broadband is an innovation. The development of high capacity and intelligent networks has involved a multiplication as well as a qualitative diversity of applications. Some of the more prominent examples are data transfer, home banking, video on demand, videoconferencing, online services, Voice over Internet Protocol (VOIP), e-commerce and m-commerce. An open set of services, sometimes referred to as Pretty Amazing New Services (PANS), is now available and contrasts greatly with the former telecoms system, which provided Plain Old Telecommunications Services (POTS), i.e. a closed set of services such as the transmission of voice calls and the fax (Savage and Waldman, 2005; Laffont and Tirole, 2000). In the line with some recent contributions (Chesbrough, 2003; Fransman, 2004; Christensen, Olesen and Kjaer, 2005), and also older ones (Loasby, 1991, 1999), broadband and, more generally, packet-switched systems, correspond to an open system of innovation, while circuit-switched systems were closed innovation systems.

2.2. Is broadband an autonomous or systemic innovation?

Whether broadband is an autonomous or a systemic innovation is a more intricate question. We could simply consider – as many commentators do – that this innovation development is like a 'plug' of compatible components, which is commensurate with the idea of an autonomous innovation[2].

However, here, we favour a more processual or dynamic vision of broadband as a systemic innovation. Broadband is the outcome of a complex combination of technologies developed by firms whose core activities are related to industries that previously were separate (the telecommunications industry for the development of infrastructure; the computer industry – hardware and software – for the development of equipment, navigation and security facilities; press, information and broadcasting sectors for the elaboration of content in broadband Internet services). These industries progressively merged to form a distinct industry, the broadband industry, with a layered structure composed of complementary assets including

[2] The idea of modularity is present here, see Langlois (2002), Brusoni and Prencipe (2001), and Brusoni (2005).

R&D in broadband products and services, production/commercialization of network facilities, and commercialization of basic, improved and advanced services. This successful combination of technologies, activities and assets was not achieved spontaneously, since high uncertainty prevailed, and continues to prevail, about the viability of the whole system. In addition, their combination required elaboration of specific interfaces and organizational arrangements both by companies already present in these industries, but also by new emerging companies. In many case, these latter generated new layers that needed to be articulated with existing ones.

2.3. Description of the layers: a set of complementary activities

We define the broadband industry as a set of complementary activities, arranged in vertically-related layers[3] (see Table 1).

<table>
<tr><th>Layers</th><th>Activities</th><th colspan="2">Firms</th></tr>
<tr><td rowspan="3">Layer 1</td><td rowspan="3">Equipment provision</td><td colspan="2">Equipment suppliers</td></tr>
<tr><td>Incumbents</td><td>Entrants</td></tr>
<tr><td>Lucent, Alcatel, NEC, Nortel,</td><td>Cisco, Ascend, BayNetworks</td></tr>
<tr><td rowspan="3">Layer 2</td><td rowspan="3">Network operation</td><td colspan="2">Network operators</td></tr>
<tr><td>Incumbents</td><td>Entrants</td></tr>
<tr><td>AT&T, France Telecom, Deutsche Telekom, BT, NTT</td><td>Worldcom, Free, Tele2, Mannesman, Mobilcom,Vodafone</td></tr>
<tr><td>Layer 3</td><td>Internet access and service provision</td><td colspan="2">IAPS and ISPs: Wanadoo, Freeserve, T-online</td></tr>
<tr><td>Layer 4</td><td>Navigation and security provision</td><td colspan="2">Browsers, data protection companies: Netscape, Yahoo!, Google</td></tr>
<tr><td>Layer 5</td><td>Content provision</td><td colspan="2">E-commerce, broadcasting and information companies: AOL-Time Warner, Vivendi Universal</td></tr>
</table>

Table 1: The info-coms industry in the age of broadband

Layer 1

Description: The 'equipment provision layer' (Layer 1) comprises firms (equipment suppliers) specialized in the **conception and development** of switches, transmission

[3] See Fransman (2001, 2002, 2004); Krafft (2003, 2004); Fransman and Krafft (2002). The activity-based layer model developed here has connections with the idea of strategic groups introduced in the strategy literature by Hunt (1972), Caves and Porter (1977) and Porter (1979). For recent investigations into this connection in the info-coms industry, see Sabat (2002) and Li and Whalley (2002).

equipment, routers, servers and billing software. Within this layer, competition comes from the interaction between incumbents such as Lucent (previously owned by AT&T), Alcatel, Siemens, Nortel, NEC and new firms such as Cisco, BayNetworks, Ascend, Nokia and Ericsson, which developed out of Internet and mobile activities. This competition tended to produce waves of mergers between the two categories of firms, especially between incumbents and new firms (see for instance acquisitions such as Lucent-Ascend, and Northern Telecom-Bay Networks, now Nortel).

Complementarity with Layer 2: Layer 1 provides Layer 2 with the equipment (highly R&D intensive) dedicated to network operation and management in the domain of fixed and mobile telephony, the Internet and multimedia. This complementarity, i.e. the way in which this provision is mediated, is not necessarily based on pure market relations. More cooperative arrangements are often required, such as the secondment of specialized engineers or technicians from companies in Layer 1 to companies in Layer 2 to run the technological systems, or to elaborate joint projects on the development of specific innovations.

Layer 2

Description: The 'network operation layer' (Layer 2) comprises firms involved in the **production** of network infrastructures and services. Within this layer, incumbents (AT&T, France Telecom, Deutsche Telekom, BT, NTT) had to face competition from new entrants (Worldcom, Free, Tele 2, Mannesmann, Mobilcom, Vodafone), whose entry was favoured by the liberalization and the development of new modes of communication (fixed and mobile Internet). Entrants generally were performing well until the financial crash that occurred in 2000; following this, a stable oligopoly of incumbents reemerged.

Complementarity with Layer 3: Layer 2 provides Layer 3 with the infrastructure required for Internet connectivity. To achieve this complementarity between Layer 2 and Layer 3, firms first undertook vertical specialization; however, they later undertook mass adoption of vertical integration (although some reverted to a strategy of vertical specialization).

Layer 3

Description: The 'Internet access and services provision layer' (Layer 3) comprises firms (IAPs and ISPs) involved in the **commercialization/distribution** of basic Internet services (e-mail, web hosting). These firms appeared as a result of the increasing development of the Internet. However, there is a great heterogeneity among these firms: some are facilities-based and own their own networks while others are facilities-less and simply lease the network that

others have developed; some are large and increasingly diversified while others are small and exclusively specialized; some provide free Internet services while others charge for these services. Exclusively specialized, facilities-less, and free Internet companies have tended to perform less successfully, and eventually exited the broadband market or were acquired (AOL, for instance, exited Layer 3 and consolidated its activities in Layer 4 and Layer 5 through the acquisition of Netscape and Time Warner; Yahoo! and Google also moved to Layer 4).

Complementarity with Layer 4: Layer 3 provides Layer 4 with Internet connectivity, a basic commodity which can be complemented by value-added services. This complementarity is increasingly based on a vertical integration between Layers 3 and 4.

Layer 4

Description: The 'navigation and security provision layer' (Layer 4) comprises firms involved in the **commercialization/distribution** of search engines, browsers, portals, secure electronic payment facilities, firewalls and data protection services. Highly connected with the Internet revolution, most of these firms have appeared relatively recently in the industry. However, because this layer is directly related to computing and software activities, older, established computer and software companies, such as IBM and Microsoft, are also present in this layer, but tend to be less efficient than new firms such as Netscape, Yahoo!, Copernic, and Google.

Complementarity with Layer 5: Layer 4 provides Layer 5 with a new medium, the Internet, the applications of which have to be developed and distributed. This complementarity is increasingly requiring vertical integration between Layers 4 and 5.

Layer 5

Description: The 'content layer' (Layer 5) comprises firms involved in the **commercialization/distribution** of web design services, online services, e-commerce, information services and broadcasting services. Within this layer, a large diversity of firms have recently been involved in competition. Small new firms specialized in web design and e-commerce (the 'dot-coms', one of the most specific examples being Amazon) initially performed incredibly well, but later suffered a fall in financial performance and competitiveness. The older established information and broadcasting firms diversified into Internet activities and penetrated the 'content layer' of the info-communications industry (see Bloomberg, Reuters, and Time Warner). Layer 5 provides customers with a wide spectrum of advanced (secure and multi-content) Internet services.

2.4. Complementary assets or complementary activities?

So far, we have not made a strong distinction between assets and activities, and the two notions have been used interchangeably. However, we need to be more specific and precise for the following reason. Neighbouring layers of the industry represent complementary activities, but this does not mean that they necessarily represent exactly complementary assets as understood by Teece. We thus need to clarify a) what kinds of complementary assets are being referred to, b) the conditions under which firms are required to have access to complementary assets, and c) how they can access these assets.

Teece (1986) starts from the key notion of the core technological know-how in innovation that he defines as "how to do things better than the existing state of the art" (p. 288). This know-how is partly codified, partly tacit, and in order for it to generate profits, it must be sold or utilized in some fashion in the market. Yet, in most cases, the successful commercialization of an innovation requires that the know-how in question be utilized in conjunction with other capabilities or assets. He thus advances that services such as marketing, competitive manufacturing, distribution, services and complementary technologies are almost always needed, and are often obtained from complementary assets which are specialized. He gives the example of the commercialization of a new drug which is likely to require the dissemination of information over specialist channels (this idea was further developed in Arora and Gambardella (1994), and related articles), and the example of computer software which typically requires specialist software for both the operating system and applications (see recent developments on this by West (2003) and Chesbrough (2003) on open source; and Funk (2003) on cell phones).

The whole system as presented in section 2.3., and decomposed into five layers, corresponds to an extended production process in the Teecian framework in which conception, manufacturing, commercialization and distribution are present.[4] There is an obvious technical link between the different layers: to operate the network, network infrastructure and

[4] One could also focus on complementary assets within one particular layer. In our case, however, this option would significantly restrict the global vision of the broadband industry that the paper is trying to develop. Moreover, complementary assets à la Teece were already used to explain the close relationships between firms that are not in the same industry. See for instance the literature on the connection between pharmaceuticals and biotech companies (Arora and Gambardella, 1994). To some extent, this suggests that the boundaries of a very innovative industry cannot be considered as fixed, but rather as evolving through the strategies implemented by firms, including strategies for the access to complementary assets.

equipment at customer's premises are required; also Internet access and services, and further content and security, are provided on the basis of the network infrastructure. However, and more importantly, these different subsystems can also be said to be linked from an economic point of view (see Table 2). Layer 1 provides most of the R&D on products and processes. Layer 2 essentially provides products and commercializes network facilities. Layer 3 commercializes and distributes basic connection services. Layer 4 commercializes and distributes improved services related to the selection and security of the information provided over broadband. Layer 5 provides end-users with an advanced set of services related to applications and content.

Layers	Activities	Assets
Layer 1	Equipment provision	Conception, development, R&D on broadband products and services
Layer 2	Network operation	Production/commercialization of network facilities
Layer 3	Internet access and service provision	Commercialization/distribution of basic services
Layer 4	Navigation and security provision	Commercialization/distribution of improved services
Layer 5	Content provision	Commercialization/distribution of advanced services

Table 2: Activities and assets in the info-coms industry in the age of broadband

Each layer regroups firms that share core technological know how, i.e. they know how to do things better than firms located in other layers. For instance, firms in Layer 1 know how to do R&D better than firms located in Layers 2, 3, 4, and 5. But in order for such knowledge in R&D to generate profits, this knowledge has to be utilized in conjunction with other assets, such as production/commercialization of network facilities (assets in Layer 2), commercialization/distribution of basic services (assets in Layer 3), improved services (assets in Layer 4), and advanced services (assets in Layer 5).

It is significant that the idea of core technological know-how, and thus the location of companies in a given layer, inevitably shapes the strategies implemented. This suggests some connections between our framework and the strategy literature. In the strategy literature, the concept of strategic group describes a group of firms with similar strategies, which are different from those being adopted by other firms in the same industry. In our framework, strategies are based on firms' backgrounds (comprising core technological know-how,

specialized assets, specific domains of activity), which enable some types of action, but may inhibit others. Another point of connection is that the strategic decisions made by a firm within a strategic group cannot be imitated by firms outside the group without substantial costs, and thus there are barriers to imitation. In our framework, firms cannot always evolve from one layer to the other without the prior acquisition of the technological know-how that prevails in the targeted layer, or in other words without investment in the complementary assets that characterize this layer.

2.5. The evolving nature of complementary assets: from generic to co-specialized

Over time, the nature of complementary assets in the info-coms industry has changed. At its origins, i.e. in the era of narrowband, the Internet required the combination of technical interfaces to provide a set of basic services, such as e-mail, file transfer, and the design and hosting of websites. Firms were required to combine generic assets that did not need to be tailored to the innovation. The predominance of generic assets, articulated through technical interfaces, favoured the entry of firms whose activities were largely outside the telecoms/Internet field. A good example is the Transmission Control Protocol/Internet Protocol (TCP/IP) which facilitated the transfer of bits across different networks, many of which used significantly different technologies. TCP/IP has enabled a technical separation of the network layer (Layer 2) from the service layers above it (Layers 3, 4, and 5). This meant that service providers did not need to own or control their own networks, but could depend on network services bought on the market from network operators. It also meant that the broadcasting and information groups were able to penetrate the industry by offering "content" services as a diversification of their core activities, which belonged to a distinct industry, the media industry.

With the development of broadband, and the open set of applications and services provided by it, the key issue for firms in the different layers now is differentiation: what kind of combination with upstream/downstream firms will produce a service that is different from that being provided by direct competitor(s)? As a result, assets have become progressively specialized (involving a unilateral dependence between the innovation and the complementary assets) and even co-specialized (involving a bilateral dependence). To illustrate this, it is now common practice to contract exclusive or semi-exclusive arrangements between equipment suppliers and network operators, or between network operators and navigation, security or

content companies in the development of broadband services (see Vodafone/Vivendi Universal; Yahoo!/Verizon, AOL-Time Warner/Worldcom).

2.6. The layered structure as a road map: searching out the relevant capabilities to access complementary assets

Though decisive, description of the complementary assets needed to develop an innovation can only be considered as a preliminary step in the exercise (Williamson, 1985). Throughout the 1990s, various studies were published showing that the access to complementary assets is even more important than the assets themselves. The role of capabilities in accessing these assets is especially important. The notion of "dynamic capabilities of firms" developed by authors such as Loasby (1991, 1999), Kogut and Zander (1992), Teece and Pisano (1994), Langlois and Robertson (1995), and Teece (1996) furthered the debate by highlighting that the rationale for competitive advantage was based on the capacity of firms to access the complementary assets required for the development of their innovations. This capacity is essentially based on how firms develop their capabilities in a changing environment, i.e. how they adapt, integrate, and reconfigure internal and external organizational skills, resources, and functional competences over time, i.e. along the entire innovation process[5].

This literature was greatly inspired by the early writings of authors such as Marshall and Schumpeter, and more recently of Penrose and Richardson. Penrose (1959) has become an essential reference work on the role of capabilities. Penrose depicted, with the greatest clarity, that production has to be undertaken by human organizations embodying specifically appropriate experience and skills. She gives excellent accounts of how companies grow in directions set by their capabilities and how these capabilities expand and alter. She also showed that competitive advantage required both the exploitation of existing internal and external firm-specific capabilities and newly developed ones[6]. She had the intuition that capabilities interact with activities carried out by firms, an intuition that has been at the core of later work[7]. Richardson's (1972, 1990, 1998) contributions on the link between capabilities

[5] See also for related contributions on the topic in the domain of evolutionary theory, Antonelli (2003), Dosi and Malerba (2002), Saviotti (2003), Pavitt (2001), Metcalfe (1995), Witt (2003), and of course Nelson and Winter (1982).
[6] This idea was further extended and clarified by Teece (1982) and Wernerfelt (1984).
[7] Indeed, many recent contributions have focused on the question of the relationship between the different notions of capabilities (in a Penrosian sense) and competences (in the sense of Prahalad's and others' contributions). Afuah and Utterback (1997, p. 183), for instance, stress that "competences + firm-specific assets

and activities has certainly been too often overlooked. Recent contributions on dynamic capabilities have reaffirmed the centrality of this link. But, Richardson in his 1972 article was already arguing that it is convenient to think of an industry as carrying out an indefinitely large number of activities, activities related to the discovery and estimation of future needs, to research, development and design, to the execution and coordination of processes of physical transformation, the marketing of goods, and so on. He stressed that these activities must be carried out by organizations (i.e. the firm, the market or the cooperation) with appropriate capabilities, or, in other words, with appropriate knowledge, experience and skills. He proposed the following distinction between similar and complementary activities: activities whose undertaking requires the same capability are similar activities, and activities that represent different phases in a process of production (and, consequently, do not necessarily require the same capabilities) are complementary activities[8].

The arguments developed by in these early works or by the dynamic capabilities literature on the link between activity, assets and capability, have become the key to transforming a purely descriptive layered decomposition of the industry into a road map[9].

On the basis of this road map, we can analyse why the different companies locate in the different layers, based on their initial capabilities, and how they are able to evolve from one layer to the other with the development or acquisition of new capabilities. We can study why and how equipment suppliers (Layer 1) have accumulated capabilities related to the conception and development of switches, transmission equipment, routers, servers and billing software through investing heavily in R&D assets. Network operators (Layer 2), on the other hand, have focused their capabilities on the provision of network facilities, and thus concentrated on the assets of production (of the infrastructure). Finally, firms in Layers 3, 4, and 5 have centred their capabilities on the commercialization and distribution of broadband services, ranging from basic to advanced. Each of the companies located in the various layers, embodies a specific type of asset and related capabilities that need to be combined in an appropriate way, in order for the technological innovation of broadband to be transformed into a commercial opportunity. We can also assess from the road map, in terms of layers,

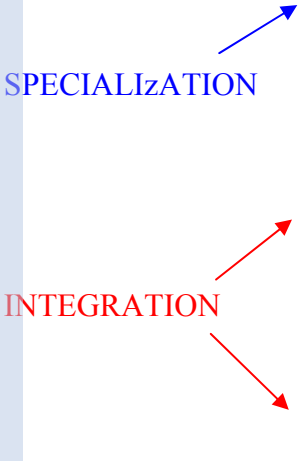
---

= capabilities or resources (in the Penrosian sense)". Foss (1997) also provided a fine classification on the different notions of competencies/capabilities, as well as on the different notions of activity (including Porter).

[8] These definitions strongly support and shape the framework in terms of the layers described in Section 2.3. These definitions also complement point made in Section 2.4. that complementary activities are compatible with complementary assets in Teece's meaning.

[9] See also on the advantages and drawbacks of using a layer representation of the industry (Fransman 2002).

whether the specialization strategies in one layer, or alternatively the evolution towards other layers via integration or cooperation, have been profitable, and why, on the basis of the ability or inability of firms to mobilize the relevant capabilities. Previous work has shown that Layer 1 has tended to be vertically specialized since the early stages of telecommunications liberalization (Fransman, 2001, 2004; Krafft, 2003, 2004, and see Table 3).



Layers	Activities	Firms	
Layer 1	Equipment provision	Equipment suppliers	
		Incumbents	Entrants
		Lucent, Alcatel, NEC, Nortel,	Cisco, Ascend, BayNetworks
Layer 2	Network operation	Network operators	
		Incumbents	Entrants
		ATT, France Telecom, Deutsche Telekom, BT, NTT	Worldcom, Free, Tele2, Mannesman, Mobilcom,Vodafone
Layer 3	Internet access and service provision	IAPS and ISPs: Wanadoo, Freeserve, T-online	
Layer 4	Navigation and security provision	Browsers, data protection companies: Netscape, Yahoo!, Google	
Layer 5	Content provision	E-commerce, broadcasting and information companies: AOL-Time Warner, Vivendi Universal	

Table 3: Vertical specialization/integration in the info-coms industry at the age of broadband

But how is broadband affecting this vertical specialization? How are the traditional companies, namely the old equipment providers, incumbents in the telecoms industry, interacting with the new ones from the software industry? Is a merger between the old and the new the solution in terms of development of adequate capabilities? Again, existing evidence shows that Layers 2 and 3 first embarked on a strategy of vertical specialization, later turned to vertical integration and recently seem to be reverting to vertical specialization. But is this vertical integration robust to the generalization of broadband services? Does this structure allow the adequate development of capabilities? These questions are at the centre of the two stylized facts we examine next.

3. SF1: "R&D and patent licensing are increasingly high in this industry, but the initiators of innovations have changed greatly over time"

Here, we discuss how R&D and production assets, i.e. conception of equipment (activity in Layer 1) and provision of network facilities (activity in Layer 2), are combined to generate profitable (or less profitable) outcomes. For a long time, these assets were integrated within a single category of firms, the network operators, which had accumulated R&D capabilities in basic electrical instruments (cables, semiconductors, aerials), and also some manufacturing capabilities related to the production of electronic communication techniques (transmission, multipoint communication, digital information). In the mid 1990s, R&D assets and related capabilities were progressively disintegrated by network operators to upstream suppliers, the equipment providers, the network operators retaining only the production assets. In what follows, we document these changes focusing on the key stylized fact that R&D and patent licensing have always been important in this industry, but in the broadband era are even more important, and that firms investing in R&D assets have changed radically over time. We discuss how this stylized fact fits with Teece's framework, and analyse a) the positive impact SF1 had on the entry of new firms, and b) the subsequent negative impact it had on the initial developers of the new technology.

3.1. Changes in the source and nature of innovation

Quantitative and qualitative change

Since the mid 1990s, firms in Layer 1 (equipment suppliers) faced a dual challenge[10], which greatly affected their innovative strategy:

- A quantitative net increase in their R&D spending was necessary, since their clients – firms in Layer 2 (network operators) – which formerly were the major technology providers had decided to exit this activity in a context of fierce price competition and full liberalization.
- A qualitative improvement of the technologies to be provided was needed for an extended set of applications, since "closed" traditional telephony (fixed telephony on copper wires based on switch and transmission systems) was being superseded by new

[10] The reference to a 'dual challenge' is a simplification. For a more detailed description of what occurred in the telecommunications equipment industry, see Fransman (2002), Calderini and Garrone (2002), Hicks (2001); Krafft and Ravix (2005).

"open" modes of communications (broadband Internet connection and related services, provided through different media such as DSL technologies, radio access, satellite connections, optical fibres).

A massive "shifting in the knowledge base [know-how in Teece's terms], from network operators to equipment suppliers" (Fransman, 2001, p. 109) occurred at this time, in relation to both the sources and nature of innovation. The change in the source of innovation derived from the fact that firms in Layer 2 were progressively delegating R&D activity to firms in Layer 1 and that Layer 1 firms were proving not only to be efficient subcontractors but also active innovators. The change in the nature of innovation was due to the fact that traditional equipment suppliers (such as Lucent, Nortel, Alcatel) were having to compete with new firms in Layer 1 (such as Cisco, BayNetworks, Ascend), which had their origins in the software and data processing industries and whose R&D capabilities could easily and quickly be extended to the conception and development of Internet and broadband technologies.

In terms of R&D, Fransman (2001, 2004) reports that, within a few years, the initial split in R&D expenses (on average, 15% of annual sales for network operators, 5% for equipment suppliers) was completely reversed (thus 5% of annual sales for network operators, and 15% for equipment suppliers). Moreover, he shows there was a disparity in R&D expenses in Layer 1: new firms were generally investing more than 15% of their annual sales, while traditional equipment suppliers were investing around 10%.

In terms of patent licensing, Figure 1 shows that firms in Layer 1 patented much more than firms in Layer 2 whose patent rates stagnated up to the 1980s. Figure 1 also illustrates the decoupling that occurred among firms in Layer 1, new firms becoming the leaders of innovation, while older, incumbent or traditional firms lagged behind.

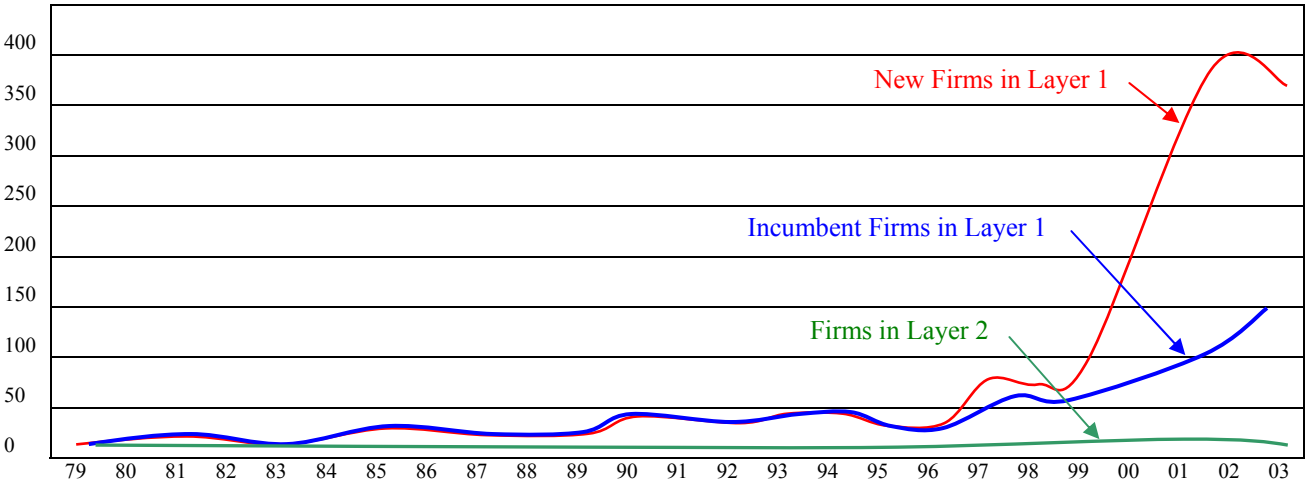


Figure 1: Evolution of the number of patents by firm on average
(Technology Class H04 L: transmission digital information, source: EPO)

3.2. Connection with Teece (1986)

Teece's (1986) theory was that a profit seeking innovator, confronted by the need to access specialized complementary assets and/or capabilities, would be forced to expand its activities through integration or collaboration if it were to prevail over imitators. The Annex to this paper reminds us that situations differ depending on (i) the degree of intellectual property protection, and (ii) the market power of innovators/imitators versus owners of complementary assets.

SF1 concerns the first situation described by Teece whereby[11]:

- There is a strong legal appropriability regime: each and every innovation can be adequately covered by a patent, and firms increasingly rely on legal appropriability regimes to protect their innovation. The significant rise in patenting activity (see Figure 1 above) since the late 1990s coincides with the spread of broadband and confirms that firms (especially in Layer 1) have a stronger interest in protecting their innovations than in the narrowband era.
- The innovators and imitators (Layer 1 firms) are advantageously positioned vis à vis independent owners of complementary assets (Layer 2 firms). Firms in Layer 1 have invested heavily in R&D (on average at three times the level of firms in Layer 2) and thus appear to be the leading companies in the industry. The capacity of many network

[11] This situation is denoted (1) by the author.

operators (especially those that perform little or no R&D) to provide end-users with advanced services on the basis of high capacity and intelligent networks depends on the technological know how of firms in Layer 1, and the variety and performance of the products and processes they generate. Thus it can be seen that firms in Layer 1 are exerting, in Teece's sense, an important market power over the owners of complementary assets (firms in Layer 2).

Figure 2 below provides a focus on this first situation and predicts that, in a Teecian framework, Firms in Layer 1 (the innovators) would win.

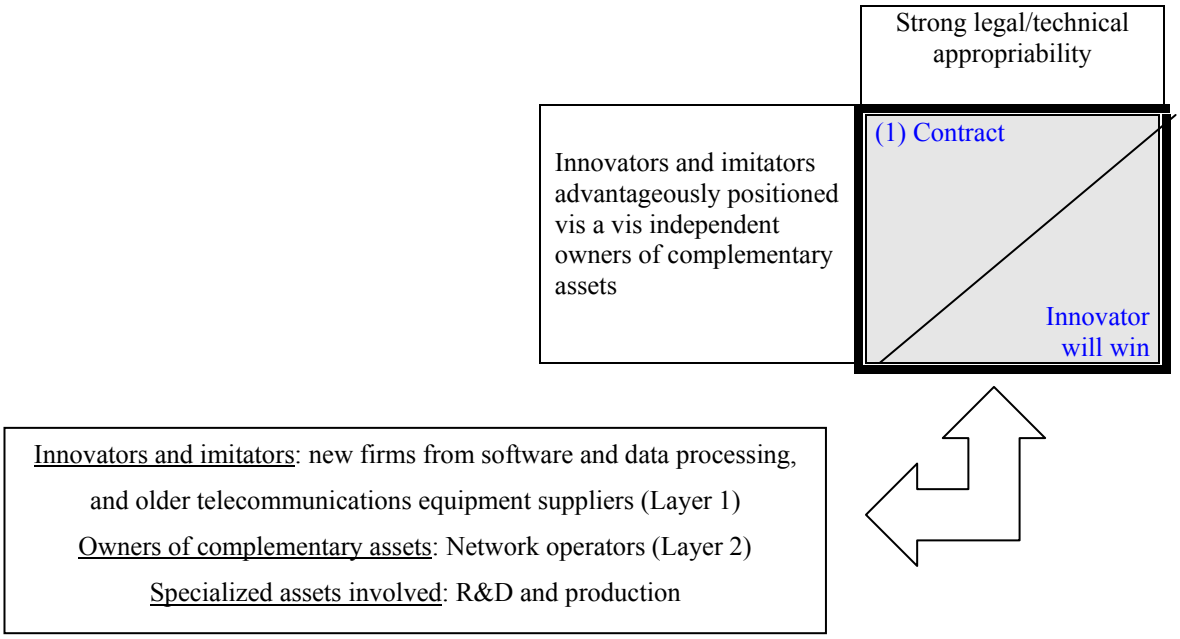


Figure 2: A focus on contract, integration strategies, and outcomes for firms in Layer 1: R&D and production specialized assets in the broadband industry

In what follows, we will see that firms in Layer 1 are effectively highly specialized and contract with firms in Layer 2 to couple their innovation with complementary network assets. However, the real innovators in Layer 1 (new firms) did not necessarily win, since they suffered a massive programme of acquisition by their competitors and imitators, the older traditional firms, the incumbents.

3.3. The positive impact of SF1: emergence of distinct complementary assets, vertical specialization and entry

In the early 1990s, distinct assets progressively emerged among Layer 1 and Layer 2 firms, based on complementary capabilities. Liberalization in communications infrastructure and services triggered important restructurings in the major R&D labs (Bell labs and Bellcore in the US, CNET in France, CSELT in Italy, BT labs in the UK). Most were historically related to incumbent firms in Layer 2 (the ex-monopolies), and the emergence of competition affected them in two essential ways: companies began to outsource, and the labs had to be significantly downsized[12]. This phase of the restructuring left some room for upstream actors, the equipment providers, to operate as the main generators of technology, while downstream actors, the network operators, began to specialize in mass manufacture of infrastructure and related services.

On the one hand, firms in Layer 1 undertook a significant development and refocusing of their capabilities. Incumbent firms in Layer 1 became more dependent on firms in Layer 2, even more so than in the pre-liberalization period. Equipment suppliers took the initiative to transform their capabilities, which, for a long time, had been related to their development as subcontractors in programmes initiated by firms in Layer 2, at that time historical monopolies, into new capabilities were more related to fundamental research and innovation activities. From the mid 1990s, they massively invested in R&D, recruited experts, researchers and engineers in physics (optics) and electronics (cable, satellite), increased their patenting activity, and thus became the leaders in the info-communications industry in terms of innovation in the broadband era. They successfully diffused these innovations to the downstream level (the network operation level, or Layer 2) by offering tailor-made applications to new entrants in network operation, applications associated with a large spectrum of assistance and maintenance services.

On the other hand, Layer 2 underwent a similar refocus. Since there was a fierce competition over prices and capacities due to the increasing traffic and diversified applications related to

[12] In the US, the Bell labs account for 5,000 employees in 2006 only 1,000 of which are engaged in research projects. Many senior researchers left to join Princeton, Columbia and Carnegie Mellon. The research budget was reduced to $1.2 billion about a third of the level 15 years earlier. In parallel, research was refocused: most of the long term projects in physics (optical elements, digital data processing) were discontinued or outsourced to public and private research groups (universities, R&D divisions of equipment suppliers), and replaced by shorter, end-user oriented projects (transmission techniques).

the Internet, firms in Layer 2 were making high investments in network infrastructure, end-to-end connections, and broadband services. Incumbent firms in Layer 2, which previously had controlled most of the research activities, radically reorganized their R&D divisions, reallocating budget and employees to other divisions, mostly commercialization and marketing. They voluntarily delegated their innovation activities to equipment suppliers, and transformed their capabilities in this domain[13]. In France, for example, 200 employees left France Telecom's R&D organization (formerly CNET). Researchers and engineers were encouraged to create their own start ups, and spinoffs. People working in the administration area were generally allocated to more commercial and marketing jobs within France Telecom. This occurred in a context in which new network operators were entering Layer 2 without having their own R&D activities or related capabilities, but nevertheless generating large revenues from the persistent growth in demand, and eventually outperforming the incumbents.

From the early stages of liberalization to the spread of broadband, specialization dominated in Layers 1 and 2, based on the emergence of two distinct complementary assets (R&D and production). The penetration of firms from Layer 1 to other layers was a rare and temporary phenomenon; similarly, the penetration of firms from other layers to Layer 1 was shortlived. This vertically specialized structure was robust to radical changes, and generated positive effects. Within this vertical specialization, incumbent firms in Layer 1 could refocus their activities on the challenges brought by the Internet (Lucent, Alcatel, Nortel), and new firms in Layer 1 were able to emerge and perform extremely well up to the early 2000s (Cisco, BayNetworks, Ascend). This vertical specialization also fostered competition in Layer 2. New network operators could enter the industry and remain viable in the face of large, incumbent companies, since they could rely on firms in Layer 1 to access the complementary assets (R&D, patents, innovations, technologies) and related capabilities that they were unable to develop by themselves.

[13] This is often described in the literature as "knowledge flows", "knowledge moves", or "development and alteration of capabilities". See Birkinshaw (2005) in a general context, or Carpenter, O'Sullivan and Lazonick (2003) for the specific field of telecommunications.

3.4. The negative impact of SF1: a massive process of M&As affected the early innovators

New quantitative and qualitative challenges to firms in Layer 1 involved large innovation R&D investments, and a re-orientation of the initial know-how towards the development of new capabilities. Various business strategies were introduced by incumbents and new entrants in Layer 1 to match these innovation and development efforts.

First, a variety of forms of cooperation emerged over the period 1995-1998. Bilateral collaborations occurred between the major incumbents and entrants. Alcatel increased its bilateral collaborations with Ascend, BayNetworks, Cisco, and Nokia on broadband technologies and mobile access. Lucent and Northern Telecom, on the other hand, preferred more exclusive bilateral collaboration, respectively with Ascend and BayNetworks. These collaborations were intended to favour the creation and diffusion of new technologies between incumbents and entrants, to facilitate the exchange of knowledge and develop new articulated competencies, and to render quantitative and qualitative coordination in R&D assets and related capabilities possible.

Second, there was a massive wave of mergers and acquisitions (M&As) in the period 1998-2000, and especially between incumbents and entrants in Layer 1. M&As were a way of acquiring new knowledge and capabilities more rapidly than through inter-firm cooperation. Investors, shareholders and business analysts were all in agreement that, in the specific time span, the value created by M&As would be higher than the value created by cooperation (Krafft and Ravix, 2005). The biggest M&As included Northern Telecom's acquisition of BayNetworks in August 1998 for $6,900 million and Lucent's acquisition of Ascend in July 1999 for $20,000 million. During the period December 1998 to December 1999, Alcatel acquired Packet Engines ($315 million), Xylan ($2,000 million) and Newbridge ($7,100 million) in order to strengthen their optical fibre and mobile access activities. However, in the year following these M&As Nortel, Lucent, and Alcatel suffered major losses in revenue and decreasing share prices.[14].

[14] Business Week (2001, 2002).

Thus, the early innovators were taken over by incumbents, and their sources of novelty, such as specific R&D capabilities in software and data processing, which had made a large contribution to the development of broadband, became diluted with large, and certainly less efficient structures. The final step in the process is greater concentration among traditional equipment supplier: Alcatel and Lucent are currently engaged in a merger that is intended to rationalize their activities, especially R&D.

4. SF2: "Small, facilities-less companies emerged throughout the development stage of the Internet industry, but have generally performed badly when the industry matured and broadband became widespread"

In addressing this stylised fact we focus on the articulation between production and commercialization/distribution assets, i.e. provision of network facilities (activity in Layer 2) and provision of connectivity (activity in Layer 3), navigation and security (activity in Layer 4) and content (activity in Layer 5). In the era of narrowband, commercialization/distribution of basic services assets were in the hands of two distinct categories of firms, namely facilities-based companies (the network operators in Layer 2), and facilities-less companies (the IAPs/ISPs in Layer 3). But, with the spread of broadband, many of these companies that had invested exclusively in assets related to the commercialization/distribution of basic Internet services began to show poor performance. Some of the largest facilities-less companies, however, such as AOL, Google and Yahoo!, became key leaders in the industry by divesting from initial core activities (commercialization/distribution of basic services and, in some cases, network assets), and reinvesting in assets related to the commercialization/distribution of improved and advanced services. Following the procedure in Section 3, we document what occurred in the industry and discuss how it fits into Teece's framework. We analyse how, despite the key role that IAPs and ISPs played in the development of broadband, a) SF2 massively affected the population of firms in Layer 3 and caused most to exit the market since they did not have access to the complementary assets related to the commercialisation/distribution of improved and advanced services, while b) favouring the emergence of some (but very few) vertically integrated champions.

4.1. The growth and decline of ISPs/IAPS

From narrowband to broadband

Firms in Layer 3 (IAPs and ISPs) have played a major role in the development of the Internet industry[15]. Layer 3 appeared in the early 1990s when the development of the world-wide-web (WWW) allowed a multiplicity of new services such as data transmission, e-commerce and the development of web sites. At that time, vertical specialization was predominant: ISPs/IAPs, as autonomous firms independent of those in Layer 2 (network operators), contributed directly to the development and diffusion of the Internet. In fact, the technical separation (the TCP/IP interface) between the network and services implied that these ISPs/IAPs could simply lease infrastructure from the network operators, or develop points of presence on it to connect their customers end to end (see Kavassalis, Salomon and Benghozi, 1996). Moreover, although some firms in Layer 2, such as MCI and Sprint in the US, had entered the Internet business as Internet backbone providers, most were latecomers to the sector. This provided the opportunity for many small new firms to prosper and become prominent in the Internet's early stage development.

However, this role reduced over time, and especially from the mid-1990s. Several firms in Layer 2 were able to penetrate the connectivity market by means of vertical integration, i.e. either by developing Internet activities internally, or by acquiring existing ISPs/IAPs. In fact, Internet access and many Internet services (such as e-mail and web hosting) were becoming a commodity business driven by economies of scale and scope, essentially captured by network operators from Layer 2. Moreover, the advent of free Internet access was robbing ISPs/IAPs of much of their revenues and making it increasingly difficult for them to differentiate themselves. While content may have been a key differentiator (as the big ISPs/IAPs such as AOL, Yahoo! and Google recognized), the cost of differentiated high-demand content was prohibitive for many smaller ISPs/IAPs. Finally, the development of broadband Internet certainly favoured facilities-based companies, such as network operators, over the facilities-less IAPs/ISPs[16].

[15] While many studies have described the nature of broadband availability and the effects of policy on availability, little has been written from the perspective of the IAPs/ISPs. A few exceptions are Fransman (2006); Van Gorp, Maitland, and Hanekop (2006); and Greenstein (2001).

[16] Vertical integration then was the emerging structure until the late 1990s. However, recent decisions by network operators to reorganize their Internet activities into an independent structure, eventually to be listed on the stock markets, has tended to favour the rebirth of vertical specialization since 2003. In the US, for instance, AT&T decided to restructure and establish various independent companies to concentrate on Internet activity. In

4.2. Connection with Teece (1986)

Based on the Annex to this paper, which synthesizes Teece's conclusions, SF2 relates to situations (5) and (6):

- There is weak legal/technical appropriability: competitive advantage lies not so much in the technology provided by IAPs/ISPs, but rather in the spectrum of applications and services that can be offered to end-users. The Internet industry can be said to have reached a stage of relative maturity, with narrowband representing the emergence and growth phases, and broadband corresponding to the late phases of development.
- The innovators and imitators (Firms in Layer 3) are disadvantageously positioned vis à vis independent owners of complementary assets, either because they do not own network assets (developed by Firms in Layer 2), or because they have not invested in related downstream assets (such as navigation, security and content) required to provide a large range of services.

However, firms that were in existence in the era of narrowband and who on the introduction of broadband, were able to evolve their strategies of exclusive specialization in basic services to include development of navigation, security, and content activities for more advanced services, are the winners and the real innovators. Alternatively, firms that remained exclusively specialized are the losers.

This leads to two distinct scenarios as described by Teece. The first (corresponding to situation (6) in Figure 3 below) encompasses most of the smallest ISPs/IAPS, that were poorly positioned in terms of commissioning complementary assets, that were driven to bankruptcies and major failures, or were eventually acquired by network assets holders (Firms in Layer 2)[17]. The second scenario encompasses the large ISPs/IAPs such as AOL, Yahoo! and Google, which are excellently positioned with respect to commissioning complementary assets. In this case, effective vertical integration and access to other's complementary

Europe, BT was split into BT Retail, BT Ignite, BT Wireless, Yell, BT OpenWorld, and Netco (a new company). France Telecom and Deutsche Telekom also underwent some radical restructuring, with the introduction on the stock markets of their Internet divisions, structured within specific companies (see France Telecom with Wanadoo-Freeserve, and Deutsche Telekom with T-online). While the reasons for these restructurings are quite diverse, but more or less pressured by investors and financial markets, the outcome is an observed vertical specialization between Layers 2 and 3.

[17] These innovators are the losers in Teece's terms, since many were acquired when their market capitalization was already declining, and those that were not went bankrupt.

activities was the road to success. However, this required the development and integration of new capabilities, and adaptations to existing ones, i.e. it involved a highly uncertain process, especially in the context of the exploding financial bubble[18].

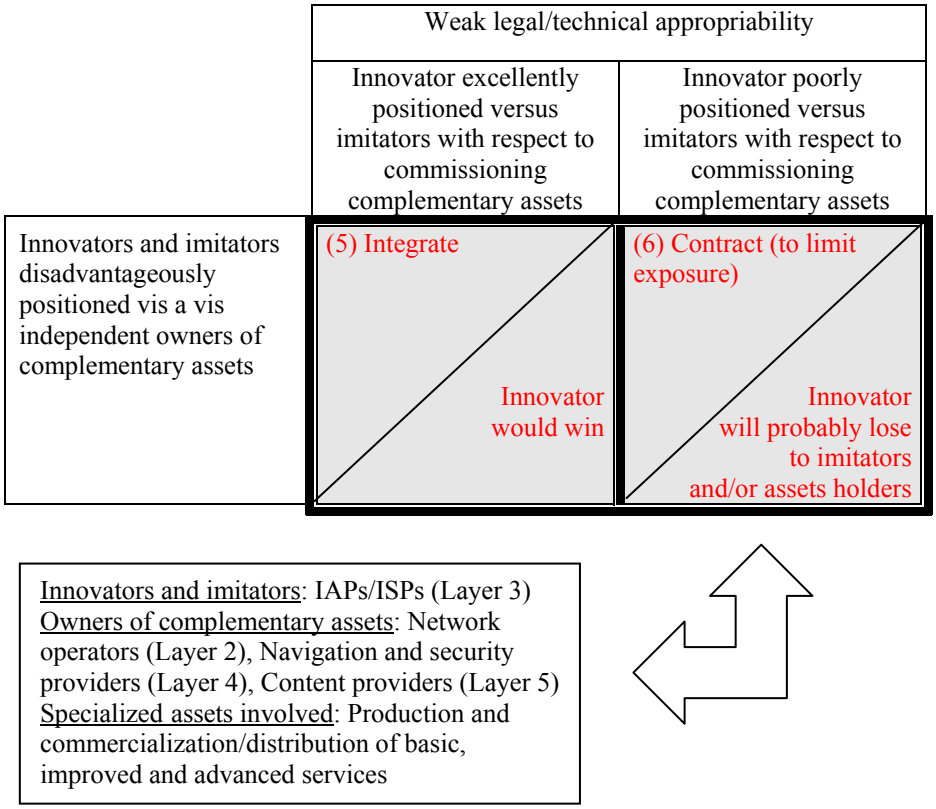


Figure 3: A focus on contract, integration strategies, and outcomes for firms in Layer 3: production and commercialization/distribution specialized assets in the broadband industry

4.3. The negative impact of SF2: massive exits of firms lacking access to complementary assets

IAPs/ISPs stimulated innovation and competition in the Internet industry. They introduced competition among many new and innovative players, some facilities-less, others facilities-based companies. They contributed to the diffusion among end-users of a major innovation by providing customers with a large spectrum of new services and enabling them to become familiar with the new medium of the Internet. Initially, then, firms in Layer 3 clearly outperformed firms in Layer 2 in this emerging business activity.

[18] These firms were able to maintain a high level of market capitalization (at least higher than most of the facilities-less companies), and used it to engage in stock for stock transactions in vertically-related businesses.

The central strategy in the development of IAPs/ISPs was specific interconnection agreements, which, from the earliest days of Internet development, were based on a specific pricing regime known as 'peering' (Srinagesh, 1997). The peering system allowed free use of the network of another company, under a reciprocity agreement. This system, which was implemented in a vertically disintegrated industry structure, was viable in the early stages of the development of the Internet. As traffic increased, however, facilities-based companies, the network operators in Layer 2, were having to cover the high costs related to the operation and management of the Internet networks while the facilities-less companies in Layer 3 (IAPs/ISPs) were enjoying use of these backbones either for free or in return for a very small payment and at the same time were charging their customers for the services they provided in the final market. The exceptions were the free Internet IAPs/ISPs, which relied on revenues generated by advertising or connected and cross activities. Eventually the incentives for firms in Layer 2 to charge for the use of their complementary network assets became too great for this situation to continue.

Firms in Layer 3 were increasingly unable to generate revenues. They became less attractive to investors and were unable to continue to access finance from banks and stock markets. The outcome was a massive shakeout among this population of firms, which either exited, or were acquired by firms in Layer 2. In Europe, 50% of these firms disappeared at the time of the financial crash, while in the US this was 70%[19]. In France, the incumbent network operator, France Telecom, merged its internal division, Wanadoo, with the ISP Freeserve, which had contributed to the emergence of the free Internet economy in the UK and Europe.

4.4. The positive impact of SF2: the survival of vertically integrated champions

Though the development of free Internet services was for some firms the key to success, many of them had tried to differentiate themselves by offering a wide spectrum of associated services, beyond basic and standardized end-to-end connectivity. This process of differentiation, however, was long and uncertain since it required the integration of new assets and related capabilities, and the disintegration of older ones.

[19] In this domain, the venture capital industry (Avnimelech and Teubal, 2004) has registered bad performance since many of these companies were mostly supported by business angels which assumed incredibly high levels of risk.

From the mid 1990s to the late 1990s, firms specialized in activities such as navigation, software/middleware, information and broadcasting activities, each of which contributed, in a rather independent way, to the development of the info-communications industry. In fact, all these firms were engaged in the development of the Internet and its associated applications, but their core activities related to industries that were previously separated: computer industry (hardware and software), press, information, and broadcasting (TV and radio programmes). The development of data transfer provided one of the first opportunities for these different firms to develop closer links with each other, as soon as the requirements of the large customers (essentially big companies) in terms of security and reliability, had emerged.

In the next stage (from the early 2000s), with the development of e-commerce and m-commerce, and the emergence of new services (secure and multi-content applications) associated with high speed Internet, the info-communications industry has been comprised of firms that are more closely connected. Even when the characteristics of final demand were still highly uncertain, firms were tending to coordinate the different (vertically-related) value-added services they were providing to customers, essentially by resorting to vertical integration. In this stage, the largest IAPs/ISPs which previously had been involved in Layer 3, began to consolidate their activities in Layers 4 and 5. These acquisitions were specific attempts to achieve viability in a (highly uncertain) innovation through the step by step articulation of vertically related activities, and systematic investment in commercialization/distribution assets for improved and advanced services. Broadband Internet and associated (safe and multi-content) applications appeared as a systemic innovation whose implementation required close coordination among the firms in different layers. As such, in accordance with Teece (1986), vertical integration seemed to provide this coordination, and favoured the conversion of end-to-end connectivity activity into more value-added activities such as navigation and content activities. Three companies adopted this strategy: AOL, Google and Yahoo!.

AOL-Time Warner: AOL was established before the Internet era as a network supplier of value-added information services, but quickly adapted to the rapidly diffusing Internet. Though some predicted that AOL would be undermined by the Internet, this did not happen. Indeed, by the turn of the century and with the spread of broadband, an astounding 40% of the total amount of time Americans spent on the Internet was within AOL's 'walled garden', essentially due to the huge capability of the company to commercialize and distribute its value

added information services throughout the web. Initially, AOL decided to develop its own network, and invested in production assets. However, this investment was essentially motivated by financial considerations: AOL's market capitalization was very high and this favoured any (even 'wrong' or at least inappropriate) types of integration. In addition, network operation was not one of the core capabilities of the company. The seeming incompatibility between internal capabilities (commercialization/distribution) and newly integrated ones (network operation), and the complex task involved in recruiting people with the skills to make the link between these two fields of activity, soon decided AOL to leave the transport of its traffic to specialists and it sold both its network (and that of Compuserve which it had acquired) to firms in Layer 2 (especially to WorldCom prior to this company's bankruptcy). In January 2000, AOL underwent a further transformation. Having abandoned its networks, it acquired Netscape, the browser, followed by Time Warner, the broadcasting company, with two purposes in mind. The first was to acquire the content that would distinguish itself from other IAPs and ISPs (and allow it to continue charging its customers a monthly fee). The second was to guarantee access to both residential and business customers by acquiring Time Warner's cable network, the second largest after AT&T's. This second transformation of AOL was smoother than the first. Though financial considerations entered into it, and eventually led AOL to focus predominantly on market capitalization, the company at this time was clearly concentrating on the development of new capabilities and articulation with existing ones. Commercialization and distribution capabilities were maintained and extended through recruitment of experts on the connection between the media and broadband. Technicians, but also economists, business strategists and lawyers, especially in the field of intellectual property rights, now figure prominently among the company's employees.

Yahoo!: Yahoo! was founded in 1994 by Stanford PhD students David Filo and Jerry Yang. Like AOL, Yahoo! does not own its own complementary network assets although, of course, it is crucially dependent on them. Yahoo!'s strategy is not to invest in production assets at a significant level, but rather to develop successful partnerships with the world's leading broadband network providers. For instance, Yahoo! provides tightly integrated and co-branded arrangements with SBC, Verizon, Bellsouth, Rogers Canada and British Telecom, offering a range of free and premium content and services to subscribers. Yahoo! has also invested heavily in complementary assets related to commercialization/distribution of advanced services, such as search activities. Yahoo! is one of the leading search engines on the web. Based on a combination of an advanced set of algorithms to ensure that results are up

to date, relevant and comprehensive, Yahoo! enables users to find anything and everything they need on the Internet instantaneously. These inner capabilities were extended to the commercialization/distribution of search engine services, while in the entertainment and high-quality media content sectors, Yahoo! has partnerships with hundreds of premier content providers.

Google: Funded by Larry Page and Sergei Brin, Google is now widely recognized as the world's largest search engine, an easy-to-use free service that usually produces relevant results in a fraction of a second. Google is based on a couple of technological innovations: *PageRank* technology, which performs objective measurement of the importance of web pages by counting the links to this page from all over the WWW, and *Hypertext-Matching* analysis, which captures the full content of a page and subdivisions, and the precise location of each word, as well as the content of neighbouring pages. Google generates revenue by providing advertisers with the opportunity to deliver measurable, cost-effective online advertising that is relevant to the information displayed on the page. This makes the advertising useful to the Internet user, and also to the advertiser placing it. Google does not own the complementary network assets, but relies on the network provided by AT&T, Sprint, Nextel, Palm, and Vodafone. However, Google has invested in developing marketing and distribution assets and services. For instance, Google AdWords is a program that promotes advertisers' products and services on the web through targeted advertising; Google AdSense delivers ads relevant to the content of the sites, improving their ability to generate revenue, and enhancing the experience for their users.

The background and trajectories of these companies are obviously different in each case. AOL initially invested in commercialization/distribution of value added information services prior to the Internet, then turned to investment in production and commercialization/distribution assets with the introduction of the Internet, and then further divested production assets, and expanded into commercialization/distribution from basic to improved and advanced services. In this latter process, it was necessary to integrate the two major companies Netscape and Time Warner, which had for years specialized in these areas. Yahoo! and Google took a different route. They first invested in commercialization/distribution of basic services in the age of narrowband. They did not invest to any significant extent in network production assets but preferred to extend their existing

assets to commercialization of improved services. They relied on partnerships for the development of the advanced services they commercialize and distribute.

Though their strategies were different, each of these business stories demonstrates that, in a weak legal/technical appropriability regime, when firms are disadvantageously positioned vis a vis independent owners of complementary assets, the key to success is to achieve a better positioning than that of imitators with respect to commissioning complementary assets. This is often accomplished by the integration of new assets initially owned by other companies, and by the development of close partnerships that allow significant transformation of internal capabilities into new ones.

5. Conclusion

One of the aims of this paper was to assess the robustness of Teece (1986) to provide a framework that was relevant to the changes that have occurred in the info-coms industry with the coming of broadband. To achieve this, we defined info-communications in terms of five complementary activities and their corresponding assets. We analysed how firms located in one activity and owning a specific type of asset were able to evolve from this activity to another (and thus invest in new assets), and especially whether this evolution was profitable or not. Focusing on two essential stylized facts that are particularly pertinent to the industry, we found that 20 years since it was published, Teece (1986) still provides a robust framework, and one that can be used to analyse who profits, and how, in the info-coms industry.

In relation to the first of these stylized facts (SF1: "R&D and patent licensing are increasing in this industry, but the initiators of innovations have changed radically over time") we show that Teece (1986) was absolutely right in maintaining that in a strong legal appropriability regime, and with innovators and imitators advantageously positioned vis à vis independent owners of complementary assets, innovators should win. We would argue that the only thing that Teece overlooked is that, given important changes in the source and nature of innovation, innovators (in our paper, the new equipment suppliers from the data processing and software industry) will eventually be acquired by imitators (the incumbent, traditional equipment suppliers).

In terms of the second stylized fact (SF2: "Small, facilities-less companies were emerging everywhere during the development of the Internet industry, but generally have performed badly as industry has matured and broadband has become widespread"), we show that Teece was right in his prediction that in a weak legal/technical appropriability regime (which in our paper corresponds to the maturity of the Internet industry in the broadband era), and given that the innovators and imitators are disadvantageously positioned vis à vis independent owners of complementary assets, the only success strategy is vertical integration. Here, we argue that what Teece might have emphasized more is that vertical integration would be the solution, provided that companies could effectively acquire and integrate the required capabilities. This was not possible for most of the smallest ISPs/IAPs, which nevertheless were active in and contributed to the development of the Internet industry.

We conclude, therefore, that there are many lessons that can still be drawn from Teece's (1986) framework and related contributions. We hope that the findings from our study might stimulate further work on two essential topics, which are closer to pure industrial dynamics issues: 1) deeper analysis of the sources of technology provision, and 2) investigation of the role of firm heterogeneity. These reflections could become the basis for a research agenda based on relating the dynamics of complementary assets and capabilities to the dynamics of innovative industries within a coherent, unique framework.

References:

Afuah, A., and Utterback, J., 1997, "Responding to structural industry changes: a technological evolution perspective", *Industrial and Corporate Change*, 6, 183-202.

Antonelli, C., 2003, *The Economics of Innovation, New Technologies and Structural Change*, London: Routledge.

Arora, A., and Gambardella, A., 1994, "Evaluating technological information and utilizing it", *Journal of Economic Behavior & Organization*, 24(1), 91-115.

Avnimelech, G., and Teubal, M., 2004, "Venture capital start-up co-evolution and the emergence and development of Israel's new high tech cluster", *Economics of Innovation & New Technology*, 13(1), 33-60.

Birkinshaw, J., 2005, "Knowledge moves", *Business Strategy Review*, 16(4), 37-41.

Brusoni, S., 2005, "The Limits to Specialization: Problem Solving and Coordination in 'Modular Networks'", *Organization Studies*, 26(12), 1885-1907.

Brusoni, S., and Prencipe, A., 2001, "Unpacking the Black Box of Modularity: Technologies, Products and Organizations", *Industrial & Corporate Change*, 10(1).

Business Week, 2001, *Lessons for the telecoms mess*, August 3.

Business Week, 2002, *Inside the telecoms game*, August 5.

Calderini, M., and Garrone, P., 2002, "The changing nature of R&D activities in the telecommunications industry", *Communications&Strategies*, 48, 53-72.

Carpenter, M., O'Sullivan, M. and Lazonick, W., 2003, "The stock market and innovative capability in the new economy: the optical networking industry", *Industrial and Corporate Change*, 12(5), 963-1034.

Caves, R., and Porter, M., 1977, "From entry barriers to mobility barriers: Conjectural decisions and contrived deterrence to new competition", *Quarterly Journal of Economics,* 91 (2), 421–441.

Chesbrough, H., 2003, *Open Innovation: the new imperative for creating and profiting from technology*, Cambridge, MA: Harvard Business School Press.

Christensen, J., Olesen, M., and Kjaer, J., 2005, "Industrial dynamics of open innovation – evidence from the transformation of consumer electronics, *Research Policy*, 34(10), 1533-1549.

Dosi, G. and Malerba, F. (ed.), 2002, "Special Issue on Industrial Dynamics", *Industrial and Corporate Change*, 11(4).

Foss, N., (Ed.), 1997, *Resources, firms and strategies: a reader in a resource-based perspective*, Oxford and New York: Oxford University Press.

Fransman, M. (Ed.), 2006, *Global broadband battles: why the US and Europe lag while Asia leads*, Stanford University Press, New York.

Fransman, M., 2001, "Analysing the evolution of industry: the relevance of the telecommunications industry", *Economics of Innovation and New Technology*, 10(2-3), 109-140.

Fransman, M., 2002, "Mapping the evolving telecommunications industry: the uses and shortcomings of the layer model", *Telecommunications Policy*, 26(9-10), 473-483.

Fransman, M., 2004, "The telecoms booms and bust 1996-2003 and the role of financial markets", *Journal of Evolutionary Economics*, 14(4), 369-406.

Fransman, M., and Krafft, J., 2002, "Telecommunications", in W. Lazonick (Ed.), *IEBM Handbook of Economics*, Thomson Learning, London.

Funk, J., 2003, "Standards, dominant designs and preferential acquisition of complementary assets through slight information advantages", *Research Policy*, 32, 1325-1341.

Greenstein, 2001, "Technological mediation and commercial development in the early Internet access market", *California Management Review*, 43(2), 75–94

Hicks, D., 2001, "Innovation dynamics and endogenous adjustment in the telecommunications industry", *Economics of innovation and New Technology*, 10(2-3), 141-168.

Hunt, M., 1972, *Competition in the Major House Appliance Industry 1960–1970*, unpublished doctoral dissertation, Harvard University.

Kavassalis, P., Salomon, R., and Benghozi, J.P., 1996, ""The Internet: a paradigmatic rupture in cumulative telecom evolution, *Industrial and Corporate Change*, 5(4), 1097-1126.

Kogut, B., and Zander, U., 1992, "Knowledge of the firm, combinative capabilities, and the replication of technology", *Organization Science*.

Krafft, J., 2003, "Vertical structure of the industry and competition: an analysis of the evolution of the info-communications industry", *Telecommunications Policy*, 27, 625-649.

Krafft, J., 2004, "Entry, exit and knowledge: evidence from a cluster in the info-communications industry", *Research Policy*, 33(10), 1687-1706.

Krafft, J., and Ravix, J.L., 2005, "The governance of innovative firms: an evolutionary perspective", *Economics of Innovation and New Technology*, 14(3-4), 1-25.

Laffont, J.J., and Tirole, J., 2000, *Competition in telecommunications*, Cambridge, MA: MIT Press.

Langlois, R., 2002, "Modularity in technology and organization", *Journal of Economic Behavior & Organization*, 49(1,), 19-38.

Langlois, R., and Robertson, P., 1995, *Firms, markets and economic change: a dynamic theory of business institutions*, London: Routledge.

Li, F., and Whalley, J., 2002, "Deconstruction of the telecommunications industry: from value chains to value networks, *Telecommunications Policy*, 26 (9-10), 451-72.

Loasby, 1999, *Knowledge, institutions and evolution in economics*, Routledge: London.

Loasby, B., 1991, *Equilibrium and evolution: an exploration of connecting principles in economics*, Manchester University Press: Manchester and New York.

Metcalfe, S., 1995, "Technology systems and technology policy in an evolutionary framework", *Cambridge Journal of Economics*, 19(1), 25-46.

Nelson, R., and Winter, S, 1982, *An evolutionary theory of economic change*, Cambridge, MA: Belknap Press of Harvard University Press.

Pavitt, K., 2001, « Public policies to support basic research : what can the rest of the world learn from US theory and practice ? (and what they should not learn), *Industrial and Corporate Change*, 10(3).

Penrose, E., 1959, *The theory of the growth of the firm*, Oxford University Press.

Porter, M., 1979, "The structure within industries and companies performance", *Review of Economics and Statistics*, 61(2), 224–227.

Richardson, G.B., 1972, "The organisation of industry", *Economic Journal*, 82.

Richardson, G.B., 1990, *Information and Investment: a study in the working of competitive economy*, Cambridge: Cambridge University Press.

Richardson, G.B., 1998, *The economics of imperfect knowledge*, Edward Elgar: Cheltenham..

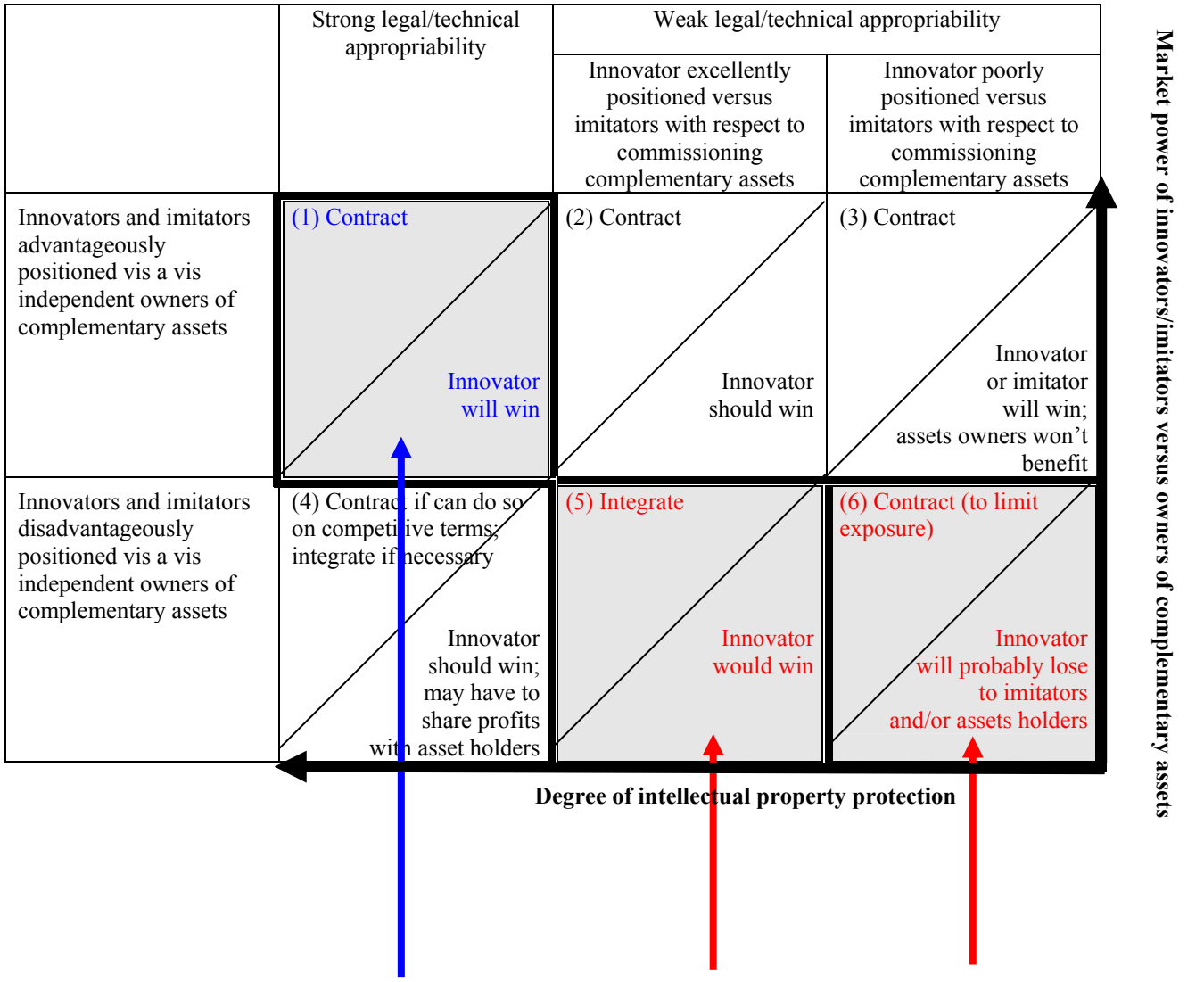
Savage, S., and Waldman, D., 2005, "Broadband Internet access, awareness, and use: Analysis of United States household data", *Telecommunications Policy*, 29(8), 615-633.

Sabat, H., 2002, "The evolving mobile wireless value chain and market structure", *Telecommunications Policy*, 26 (9-10), 505-35.

Saviotti, P.P. (Ed.), 2003, *Applied Evolutionary Economics*, Cheltenham: Edward Elgar, Forthcoming.

Srinagesh, P., 1997, "Internet cost structures and interconnection agreements", in L. McKnight and J. Bailey (eds), *Internet Economics*, Cambridge, MA: MIT Press.
Teece, 1986, "Profiting from innovation", *Research Policy*, 15(6), 285-305.
Teece, D., 1982, "Towards an economic theory of the multiproduct firm", *Journal of Economic Behavior and Organization*, 3, 39-63.
Teece, D., 1996, "Firm organization, industrial structure, and technological innovation", *Journal of Economic Behavior & Organization*, 31(2), 192-225.
Teece, D., and Pisano, G., 1994, "The dynamic capabilities of firms: an introduction", *Industrial and Corporate Change*, 3(3), 537-555.
Van Gorp, A., Maitland, C., and Hanekop, H., 2006, "The broadband Internet access market: The changing role of ISPs", *Telecommunications Policy*, 30(2), 96-111.
Wernerfelt, B., 1984, "A resource based view of the firm", *Strategic Management Journal*, 5, 171-180.
West, J., 2003, "How open is open enough? Melding proprietary and open source platform strategies", *Research Policy*, 32, 1259-1285.
Williamson, O., 1985, *The Economic Institutions of Capitalism*, New York: Free Press.
Witt, U., 2003, *The Evolving Economy: Essays on the Evolutionary Approach to Economics*, Cheltenham: Edward Elgar.

Annex: Revisiting Teece (1986): Contract, integration strategies, and outcomes for innovators in the info-coms industry at the age of broadband



SF1: "R&D and patent licensing are increasingly high in this industry, but the initiators of innovation have greatly changed over time"

SF2: "Small, facilities-less companies have generally popped up everywhere at the stage of development of the Internet industry, but have also generally performed badly when this industry matured with the generalization of broadband"