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INNOVATION AND REGULATION IN TELECOMMUNICATIONS INDUSTRY: A COMPARATIVE INSTITUTIONAL ECONOMIC ANALYSIS

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INTRODUCTION

In recent decades telecommunications industry (as well as other network industries such as electricity and railway) has been reshaped by new regulatory policies and regimes that foster competition by splitting

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functionally-integrated monopolistic operators formerly controlled by the state, allowing new private entrants. At the same time, telecommunication industry has been further concerned with high pace of innovation and R&D devoted to introducing new products and services as well as experimenting alternative industrial organisation forms. Higher innovation implies stronger presence of intangible resources as critical production inputs, involving specific accounting problems from the policy-making viewpoint. Among others, Kridel *et al.* (1996) review effects of incentive regulation in the Telecommunication Industry, while Bourreau and Dogan (2001) develop an economic analysis of the relationship between regulation and innovation.

In this context, competition-based regulatory policies and regimes are expected to enhance customers' welfare while encouraging private financing of required investments for network development and innovation, under overall conditions of efficiency, equity, and access.

Introduction of competition by regulatory design requires reshaping the mutual relationship between two main functional operators (Clusters) or intermediaries that characterise telecommunications industry: one that provides the networking infrastructure; another one providing content delivery. The driving idea is then to functionally separate infrastructure provision from content provision, which relies on access to that infrastructure network to make the communication and information contents delivered. Therefore, infrastructure provider(s) is (are) obliged by regulation to provide a universal commodity on a competitive market basis to (various) content provider(s) operating through infrastructure network(s).

Competition-based regulatory approach is based on conventional wisdom that always favours competition for welfare improvement, struggling to achieve the same conditions as would have been achieved had conditions of perfect competitive process existed (Fransman, 2008, p. 74 ff.). In fact, recent advances in regulation economics and policy cast doubts on this wisdom (Robertson and Langlois 1995), suggesting that performance-based regulatory frameworks should disentangle incentives to develop and deliver high-quality outcome at fair prices for final customers over time, from rent extraction that eventually leads to misallocation of resources and detrimental effects on welfare (Laffont and Tirole, 2000,

chapter 2, p. 37 ff.). As a matter of fact, regulatory authorities appear to be practically involved in such an effort to balance competitive separation and cooperative integration in regulated industries submitted to the introduction of competition. In particular, European Union is currently reviewing a new regulatory framework for information and communication networks and services that aims to regulate access to, and promote investment and innovation in them (Huigen and Cave, 2008). Under European Community Treaty (articles 170 ff.), telecommunications provision includes a mission of “general economic interest” for these “essential facilities” and must comply with competitive settings as well as with public interest objectives of national and trans-national integration and universal accessibility. Balance and reconciliation between these distinctive policy purposes constitutes the current agenda of national and European regulatory agencies. Since 2005, UK has adopted a regulatory scheme based on “functional separation”, which specifies terms and conditions on which access to infrastructure network(s) is granted to other operators by incumbent former monopolist. Other countries, such as Italy, Sweden, Australia and New Zealand, have been preparing functional separation regulatory schemes to be applied to their telecommunications industry. French Telecommunications Authority is also fostering a compulsory system of rules concerned with access, costing and pricing in order to assure a fair competitive process (ARCEP 2007).

Generally speaking, purpose and scope of telecommunications industry is to connect producers of contents (who originate information and communication) to final consumers (who receive them), through the interaction of two main intermediaries: operators of communication infrastructures; and providers of information services over these infrastructures. By adopting this comprehensive perspective, our paper aims to analyse telecommunications industry through its functional system of industrial relationships which produces a joint outcome. On this basis, we develop a comparative institutional economic analysis over two steps. The first step consists in developing heuristic institutional economic models of regulatory schemes of functional separation and integration. The second step consists in comparative impact assessment of both regulatory schemes on levels of (and incentives to) innovation and R&D by operators (or intermediaries) submitted to each regulation, and on the overall performance for final users (i.e., producers and consumers of information and communication contents).

The rest of the paper is organised as follows. First section subsumes some featuring characteristics of telecommunications industry into a functional system of industrial relationships. Second section provides heuristic models of this system under alternative regulatory schemes of functional separation and integration; accordingly, telecommunications industry is jointly constituted by three functional Clusters (intermediaries) which exploit four kinds of tangible and intangible resources related to innovation and R&D. Third section derives implications and recommendations from comparative assessment of these models for industrial and accounting regulations concerned with telecommunications industry.

1. UNDERSTANDING TELECOMMUNICATIONS INDUSTRY THROUGH ITS FUNCTIONAL SYSTEM OF RELATIONSHIPS

1.1. Beyond a market-based perspective: featuring facts about telecommunications industry

First of all, telecommunications industry is factually populated by relatively few, large, innovating operators which, drawing upon a core of key competencies and resources, generate a combination of products, services and infrastructures. Competitive process is then animated by a “small number” of firms (“small number competition” à la *Williamson*) which develop mutual relationships of competition and cooperation (“cooperation” according to Moore, 1996; Brandenburger and Nalebuff, 1997). Moreover, that combination of telecommunication products, services and infrastructures implies delivering a combined “telecommunication outcome” that enables connection between producers (who originate information and communication contents) and final consumers (who receive those contents). Both producers and consumers (respectively emitters and receivers of information and communication) are not so much interested in various products, services and infrastructures separately, but in the overall performance of the joint outcome of these elements. Finally, delivery of this joint outcome appears to be functionally organised by leading intermediaries, which *prescribe* the economic and social conditions of production and combination of telecommunication products, services and

infrastructures (Benghozi and Paris, 2007).¹ In this relational economic environment, key institutional structures, including accounting systems, frame and shape the ongoing productive process of creation and allocation of resources within and between firms (Biondi *et al.*, 2007). In particular, accounting structures define a conventional representation of costing and pricing that is adopted for contractual and regulatory purposes. At the same time, alternative accounting systems imply different modes of calculation for investment costs, operational costs and related remunerations of inputs and outputs within the industry, through time, space and interaction. These accounting systems settle who pays what and under which terms and conditions among various stakeholders of telecommunications system.

These featuring facts about telecommunications industry cast doubts on conventional wisdom that understands this industry through the lens of a “fair competitive process”. A market-based view (which generally underpins competition-based regulation) struggles to subsume and regulate the whole industry as if it comprises only arm’s length transactions between independent parties. However, mimicking market conditions may be misleading and eventually undermine required achievement of efficiency, equity, and access for provision of these “essential facilities”. This view understands an industrial system by looking at marketable rights on products and resources which are supposed to *pre-exist* and may then be properly priced on various telecommunications “market(s)”. This view leads to split various functional activities in distinctive markets of reference for regulatory purposes. This approach does not properly capture actual conditions that make telecommunications possible through mutual interactions between various operators and intermediaries over technical infrastructure network(s) through time and space, in a highly regulated environment through contractual and institutional arrangements. A market-based view that is merely established in terms of distinct market prices, products, and (sub-)markets misunderstands this industrial reality. For instance², Bourreau and Dogan (2001) stress the critical role of regulatory arrangements, arguing that “the present market structure of the

1 This dual structure of prescribing intermediation is partly captured by dual auction modelling. This structure makes critical the regulation of control and access for infrastructure and content providers.

2 See also Kiessling and Blondeel (1999).

telecommunications industry urges some type of control, either by means of sector-specific regulation or by competition policy. Asymmetric ex ante regulation aims at preventing the incumbent from abusing its dominant position, held by virtue of its control of the essential facility, the (ubiquitous) local access networks. [...] Therefore, asymmetric regulation also serves as a commitment device to attract entry which might not take place otherwise. [...] Contrary to regulatory policies, competition policies provide ex post control. However, employment of ex ante regulatory measures does not rule out the scope for ex post competition policies. Generally, both measures operate jointly in the telecommunications industry.”

Bourreau and Dogan (2001) refer here to widespread industrial regulatory frameworks that are better understood as purporting conditional departures from the general principle of market competition, in order to achieve welfare-enhancing industrial performances through different means. For instance, following Arrow (1959), allowance of patents and other intellectual property rights repeals from maintaining effective competition, for a limited period of time and under specific terms and conditions, in order to efficiently remunerate specific investments that develop welfare-improving R&D activities and resources. In the same spirit, accounting-based regulatory control of excessive rentability and price-making frames and shapes the competitive pricing in order to assure the proper functioning of the industrial system for public interest purposes. Moreover, regulatory control of costing implies to envelop the industrial structure of production through standardised accounting structures (ARCEP 2008) that replace competitive costing and pricing.

1.2. Telecommunications industry as functional system of relationships

Drawing upon this featuring departure from a market basis of reference and analysis, our approach aims to develop an input-output economic model that describes the whole telecommunications industry as a functional system of industrial relationships. Fransman (2008) calls it an “Information and Communication Technologies ecosystem”, while Malerba (2004) calls it a telecommunications “system of innovation”. This system performs a joint process of production that delivers a joint “telecommunication outcome”. This production process starts from

resources development, passes through costing and pricing of related functions and products, and is eventually achieved by remuneration of these products by sales to final users. This joint process of production is performed by distinctive functional operators or intermediaries (Clusters) whose joint outcome is delivered to final users (producers and consumers of content). As Holmstrom (1999) does with the economics of the business firm, our approach understands the whole telecommunication system as a “sub-economy”, departing from and expanding upon a market-based approach. Following Koopmans (1975), this model is also “pre-institutional”, that is, it looks behind the legal form (either contractual or institutional) to focalise on functional economic working that comprises technical and socio-economic aspects of telecommunications production. The whole system is then supposed to deliver a bundle of infrastructures and services (the telecommunication outcome) that allows producers and consumers of information and communication (the contents) to be connected to each other. Only the joint productive performance of this system of relationships may deliver this telecommunications outcome to final users. Our first analytical step consists in describing this outcome as a bundle of products, services and infrastructures that is jointly produced by four functional Clusters (content production; content provision; infrastructure provision; innovation and development), which, in turn, deploy four kinds of tangible and intangible resources.

1.3. The telecommunications system: the functional Clusters

Four functional Clusters describe here four key economic functions performed by operators and intermediaries in the telecommunications process of production: content production (A); content provision (C); infrastructure provision (S), and research and development (R). Table I resumes distinctive characteristics of each Cluster (we refer to the industrial economic notion of “Cluster” to stress its functional dimension; a Cluster function may be performed by a whole of business entities, typically combined in one or several enterprise groups or networks. It may further include non-business organisations and institutions).

Table I. The four functional Clusters composing the telecommunications system

	Function	Example
Cluster R	Creation of Innovation and Development	R&D institutions and department, R&D joint ventures and partnerships
Cluster S	Provision of networking infrastructures (technical delivery; technological support; telecommunications hardware)	Telecommunications firms (FT, Bouygues Telecom, and so on)
Cluster C	Provision of Contents (Costumer interface over the telecommunication network; telecommunications software)	Internet operators (YouTube, Google, Facebook), cable- and pay-televi-sions (Canal+), information agencies (Reuters), telephone operators (Skype)
Cluster A	Production of content	Movie producers, football representa-tive agencies, contents self-generated by costumers, contents produced by content providers

In particular, Cluster A denotes generation of contents originated by customers, by independent producers and by the content intermediary C. Cluster C assures interface between final users and telecommunication facilities; in particular, C performs content provision that denotes information and communication delivery through telecommunication infrastructures; this functional activity is typically accomplished by information agencies (Reuters), cable- and internet-televi-sions (Canal+), internet services and platforms (Google, Youtube, Facebook), and so forth. Cluster C treats various resources such as: users' contents; innovation and R&D from the creative Cluster R; and infrastructure facilities and services from the infrastructure provider S. Cluster S provides telecommunication facilities in all their aspects; in particular, Cluster S provides technical installation to costumers, and interacts with Cluster C to respond to specific and changing needs of content provision. S denotes then development and deployment of infrastructure facilities; this functional activity is typically accomplished by telecommunications firms (France Telecom, Bouygues Telecom, and so forth). It treats resources such as R&D and innovation from the creative Cluster R, technical installation to the costumers, and specific devices and solutions for the Cluster C. Last but not least, Cluster R captures a specific activity of innovation, research and development (R&D) that characterises the so-called "new economy" of information and communication. This Cluster constitutes an autonomous function

of telecommunication industry, assuring creative continuity and progress of the whole system through time and interaction. Therefore, its specific output is common to (and shared by) Clusters S and C, and replicates itself through time. It is generally accomplished by R&D institutions and departments, but also by the community at large (for example, through creative commons and so forth).

1.4. The telecommunications system: a taxonomy of resources

Every Cluster deploys a set of resources that our model classifies according to empirically-based accounting methods of recognition and measurement (cf. Biondi and Reberioux, 2012 for further details), labelled as tangible, “hard” intangible, “soft” intangible and “ethereal” intangible resources.

Tangible resources are material resources that come from outside the telecommunications system. Together with land and buildings, motor vehicles, furniture, office equipment, computers, fixtures and fittings, plant and machinery, this class includes personnel and its imputed monetary cost for sake of simplicity.

Hard intangible resources are intangibles that are definitively identifiable through a legal or material support making them marketable; they have then a market price of reference, making them easier to be represented. Typical hard intangibles are contents originated by Cluster A, and technical installation provided by S directly to final customers.

Soft intangible resources are intangibles that lack in legal or material support; this means that they do not have a market price of reference, and may be identified and represented only through their imputed costs; therefore, their actual contribution to the output of each Cluster is not fully covered by this measurement. Output provided by Cluster S to Cluster C is typically characterised by presence of soft intangible resources.

Ethereal intangible resources are creative commons, ideas and capabilities that replicate themselves through time, assuring continued renewal and development of the whole system of telecommunications. This Cluster draws upon tangible resources, but its contribution cannot be assessed either by

market prices imputed costs, because of its continuative and collective deployment over time; its activity may be associated with tacit knowledge, invention processes and creativity in technological and socio-economic organisation of telecommunication industry. This provision of ethereal intangibles is increasingly assured by specific R&D departments of, and joint ventures between private and public telecommunication intermediaries.

Table II. The classification of resources

$I = T, R$ $J = C, S$	TANGIBLES	Hard Intangibles	Soft Intangibles	Ethereal Intangibles
INPUTS	X_{IJ}	A	r_J	r_{t-1}
FUNCTIONS	$\frac{1}{\alpha_{IJ}}(X_{IJ})^{\alpha_{IJ}}$	$\frac{1}{\alpha_A}(A)^{\alpha_A}$	$\beta_J(r_J)$	$\beta_r(r_{t-1})$
Return to Scale	Decreasing $\alpha_{IJ} < 1$	Decreasing $\alpha_A < 1$	Constant $\beta_J \geq 1$	Constant $\beta_r \geq 1$
COSTS	$p_{IJ}(X_{IJ})$	$p_A(X_A)$	Imputed	Not Computable
Contribute to the Outputs	Direct $X_{TJ} \rightarrow D_1$ Indirect $X_{RJ} \rightarrow s_R, c_R \rightarrow D_3$	Direct $A \rightarrow D_2$	Indirect $r_J \rightarrow s_R, c_R \rightarrow D_3$	Indirect $r_{t-1} \rightarrow s_R \rightarrow R$

Table II summarises our fundamental assumptions underlying this classification of resources deployed by various functional Clusters in the economy of telecommunication industry. Both tangible and intangible resources enter the production function of each Cluster. Tangible resources are exhaustible and imply exclusive exploitation: they respond then to decreasing returns to scale. In contrast, soft intangible resources generally are “public goods”, that is, they are inexhaustible and not-exclusive: they respond then to constant returns to scale, and are expected to increase the overall performance of the set of tangible resources exploited by each Cluster. While resources that generate economic advantages include both tangible and intangible resources, recent studies argue that intangibles have the greater potential to create firm capabilities which drive economic advantages (Carmeli and Tishler, 2004). According to Constantin and Lusch (1994), knowledge-based resources are one of the most performance-enhancing forms of intangibles that are exploited in conjunction with other resources to generate multiplicative effects.

Concerning hard intangibles, their legal structure of protection makes them similar to tangible resources from the viewpoint of their exploitation and remuneration. Our model treats them as quasi-tangible resources, measured by their market price of reference. Ethereal intangibles are collectively and continuatively generated by the whole system through time; therefore, they do not correspond with any identifiable price or imputed monetary cost of the period. They may be represented only by a non-monetary system of measurements (Benston *et al.*, 2003, reviewed by Biondi, 2007), making them not computable from a contractual or regulatory viewpoint. This means that, though fundamental, their contribution to the overall performance remains interstitial and cannot be included in costing and pricing of related resources and activities. Biondi and Reberlioux (2012) address theoretical and practical challenges raised by intangibles, providing further analysis and references³.

2. AN INPUT-OUTPUT MODEL OF TELECOMMUNICATIONS INDUSTRY

2.1. The productive process of the telecommunication industry: intangibles, returns to scale and alternative institutional structures of production

Our approach especially captures a featuring aspect of telecommunications industry: the whole industry is organised around key functional intermediaries (Clusters) that develop and exploit intangible resources related to innovation and R&D processes. Since final outcome requires joint use of services and infrastructures, innovation processes are expected to require some arrangements among those intermediaries to be initiated, developed and/or implemented.

From the analytical viewpoint, our model is based upon basic assumptions on returns to scale from application of distinctive kinds of

3 See also Griliches (1998); Brynjolfsson, Hitt and Yang (2000); Schreyer (2000), Brynjolfsson and Hitt (2000), OECD (2001). Both Eurostat and the OECD have initiated programs in order to develop new measures for knowledge-based economies, improving then on related data collection (i.e. the MERITUM project).

resources to productive processes at firm and inter-firm levels (Petters and van Pottelsberghe de la Potterie, 2004). These assumptions are in line with classic approaches of industrial economics to innovation and R&D (Geroski et al., 1993; Cohen and Levinthal, 1989; Malerba, 1992). However, while other studies point whether innovation and R&D processes involve increasing returns to scale at firm, industry or country level (Romer, 1986; Jones, 1995; Young, 1998; Arrow, Ng and Yang, 1998), our model does not assume but constant returns to scale for intangible resources that characterise those processes. Management and industrial economic studies show that intangible resources denote organisational and cognitive capabilities that are generated by coordination and endurance of industrial activities over time and interaction. Their contribution expands upon productivity driven by tangible resources and personnel (Griliches, 1994; Villalonga, 2004; Zambon and Marzo, 2007). Accordingly, we assume that intangible resources delivered by R&D processes contribute to the joint production process by multiplying productivity provided by tangible resources and personnel.

Instead of focusing only on returns of scale, our approach further points to the institutional “structure of production” (*à la Coase*). Industrial and accounting regulatory regimes frame and shape the productive process performed by the telecommunication system, influencing its economic organisation of production and remuneration. From one hand, accounting systems shape representation (recognition and measurement) of tangible and intangible resources (inputs) and their imputation to different activities (and outputs) within and between distinctive Clusters (through costing). From another hand, industrial regulation frames and shapes the functional system of relationships that characterises the telecommunication industry. In particular, degree of integration (cooperation) and separation (competition) are conditional to this regulatory design. Accordingly, our model purports to assess economic performance of telecommunication system under alternative institutional designs of the production process. Drawing upon Williamson (1991), we distinguish and prioritize the first-order regulatory regime choice from the second order optimal production choice. Our model aims to firstly design the production process under alternative regulatory regimes (forms of economic organization, in Williamson’s terms), and secondly comparatively assess optimal levels of R&D and welfare under such “discrete structural analysis” (Williamson,

1991, p. 270). Accordingly, our pre-institutional input-output model – comprising four functional Clusters (respectively accomplishing R&D; infrastructure provision; content provision; and content production) which exploit four kinds of resources (respectively tangibles, hard intangibles, soft intangibles, and ethereal intangibles) – is framed and shaped by two paradigmatic regulatory designs: functional integration (Figure 1) and functional separation (Figure 2).

Figure 1. The telecommunications system under functional integration

Figure 2. The telecommunications system under functional separation

In particular, separation case describes an ideal form of regulation that establishes a fair competitive process within various “markets” of reference. This attempt implies to functionally divide the whole industry in different products having distinctive market prices, separately delivered to customers by a number of intermediaries pertaining to distinctive sub-sectors or layers which are usually identified according to technological or legal-economic characteristics of respective products and services. Regulation of competitive pricing in each sub-market of reference is then expected to assure suitable conditions of efficiency, equity and access for customers and welfare within the overall industrial system.

2.2. Model Outline

Telecommunication outcome Y denotes a bundle of telecommunication infrastructures and services jointly provided to final users. Final users are interested in the overall performance (utility) of this bundle, although they may buy its single components from different operators or intermediaries. In particular, the bundle comprises output by content provider C , called c_Y , and output by infrastructure provider S , called s_Y . Analytically, $Y \equiv (\mathcal{Y}_{C,1}, \dots, \mathcal{Y}_{C,n}; \mathcal{Y}_{S,1}, \dots, \mathcal{Y}_{S,m}) \equiv (\overline{c_Y}, \overline{s_Y})$. For sake of simplicity, let assume that⁴

$$Y = c_Y + s_Y \quad [1]$$

Final users should afford a vector of monetary payments, called p_Y , to use this bundle. This payment comprises the whole of monetary transfers performed by users and split among different Clusters during a time period of reference. From the industry viewpoint, these payments correspond to operating revenues collectively collected by (and split among) different firms pertaining to respective Clusters.

Figure 3 shows how these two elements of the bundle (c_Y, s_Y) contribute to the final outcome for customers in one illustrative case. In particular, higher is this quantity/quality generated by Clusters S and/or C , higher is the utility level (which, for sake of simplicity, can be interpreted as the sum of the two elements in a single measure of quantity/quality) of the final outcome Y .

Four Clusters contribute to produce the joint bundle Y : developer R of research and innovation; content provider C ; infrastructure provider S ; and Cluster A which provides contents generated by both final users and A itself to Cluster C . Each Cluster exploits and remunerates a definite set of resources (inputs) in order to generate another definite set of resources (outputs), according to a classic scheme of input-output analysis of production. The following paragraphs describe the production functions of these Clusters and related inputs and outputs.

4 Note that $\overline{c_Y}$ and $\overline{s_Y}$ are vectors respectively of n and m dimension. Thereafter, we omit the vectorial notation for sake of convenience.

Figure 3.

Legend: Increasing levels of final outcome Y at various prices p_y when only the quantity/quality provided by Cluster C increases from c_1 to c_2 .

2.3. Varieties of resources and their respective contribution

As discussed above (Table II), four classes of resources exist: tangibles, hard intangibles, soft intangibles, and ethereal intangibles. In particular:

Tangibles resources X_{IJ} with $I = R, S, C$ are material resources acquired from outside the Cluster at a cost p_{IJ} . By definition, X_{IJ} contributes to production under decreasing returns to scale. Analytically, their production function is then $\frac{1}{\alpha_{IJ}}(X_{IJ})^{\alpha_{IJ}}$ with $\alpha_{IJ} < 1$. To be sure, we label “production function” the contribution of input X_{IJ} to production (performed by Cluster j) of the respective component of the final bundle Y .

Hard intangible resources A are quasi-tangible resources acquired from outside the Cluster at a cost p_A . By definition, A contributes to production under decreasing returns to scale. Analytically, their production function is then $\frac{1}{\alpha_A}(A)^{\alpha_A}$ with $\alpha_A < 1$.

Soft intangible resources r_J with $J = S, C$ are immaterial resources generated by Cluster R whose cost can be measured by imputation of related investments. In particular, r_C denotes intangible resources that contribute directly to c_Y , while r_S denotes intangible resources processed by Cluster S. By definition, both r_J contribute to production under constant returns to scale. Analytically, their production function is then $\beta_J(r_J)$ with $\beta_J \geq 1$.

Ethereal intangible resources r_{i-1} are immaterial resources inherited from past investments in R&D by Cluster R whose cost is not computable. By definition, r_{i-1} contributes to production under constant returns to scale. Analytically, their production function is then $\beta_r(r_{i-1})$ with $\beta_r \geq 1$.

As discussed above (Table I), these resources are developed and exploited by four functional Clusters: content production (A); content provision (C); infrastructure provision (S), and research and development (R). These Clusters are embedded in a system of relationships that is shaped by alternative regulatory designs. The following section shall describe alternative regimes of functional integration and separation, in order to perform a comparative institutional economic analysis between them.

2.4. Functional Clusters under integration regime

Under integration regime (Figure 1), Cluster R generates soft and ethereal intangible outputs, $r_J + r_i$, through two kinds of input: tangible resources (X_{RJ}) acquired from outside, and ethereal intangible resources (r_{i-1}) inherited from its past investments in R&D. By definition, research output is indivisible and its use is not-exclusive: our model identifies then three distinctive sub-outputs, respectively called r_S , r_C and r_i , generated by the following production functions:

$$r_J = \frac{1}{\alpha_{RJ}} (X_{RJ})^{\alpha_{RJ}} \quad [2]$$

$$r_i = \beta(r_{i-1}) \quad [3]$$

with $\alpha_{RJ} < 1$, $\beta \geq 1$ and $J = C, S$.

Although the final intermediate output generated by R&D Cluster may be non-separable (entering then the production process as a unique joint input), this analytical separation is supposed here to comply with accounting recognition and measurement of various resources r_j , including ethereal resources r_i that are not recognised by accounting systems.

Cluster S generates two sub-outputs: s_Y , tangible intermediate output that enters directly in the bundle Y, and s_R , a soft intangible intermediate output that is exploited by Cluster C. These outputs are generated through three kinds of inputs: tangibles (X_{TS}), soft intangibles (r_S) and ethereal intangibles (r_i) by the following production functions:

$$s_Y = \frac{1}{\alpha_{TS}} (X_{TS})^{\alpha_{TS}} \quad [4]$$

$$s_R = \beta_S r_S + \beta_r r_{i-1} \quad [5]$$

with $\alpha_{TS} < 1$ and $\beta_S, \beta_r \geq 1$.

Cluster C generates output c_Y through three kinds of inputs: tangibles (X_{TC}), ethereal and soft intangible resources received respectively from Clusters R and S (r_C and s_R), and hard intangibles received by A. In its joint output c_Y , for sake of analytical clarity and computation, the model identifies three sub-outputs: c_T , c_A , c_R generated by the following production functions:

$$c_Y = c_T + c_A + c_R \quad [6]$$

$$c_T = \frac{1}{\alpha_{TC}} (X_{TC})^{\alpha_{TC}} \quad [7]$$

$$c_A = \frac{1}{\alpha_A} (A)^{\alpha_A} \quad [8]$$

$$c_R = \beta_C (r_C + r_i) + \beta_{SR} s_R \quad [9]$$

with $\alpha_{TC}, \alpha_A < 1$ and $\beta_C, \beta_{SR} \geq 1$.

2.5. Functional Clusters under separation regime

Under separation regime, Clusters S and C are forced to split by regulatory design. No alliances, joint ventures or other integrated activities are allowed between these main industrial intermediaries that perform respectively infrastructure provision and content delivery.

This separation involves disappearance of common Cluster R. However, since innovation and development are essential to their respective functional activities, each disintegrated Cluster S, C will respond to this net loss by internalizing its specific part of R&D that was formerly developed by Cluster R. Each remaining Cluster S, C is then expected to generate by itself those ethereal intangible resources that are specific to its functional activity. In fact, all research projects that do not directly respond to some specific and contingent needs by one of the remaining Clusters are abandoned. Furthermore, absence of these projects implies the net loss of all benefits derived by sharing expenditures and efforts in innovation and R&D over time and interaction.

Accordingly, our model removes Cluster R in case of separation regime. This implies the net loss of all the ethereal intangible resources r_i that were inherited over time by functional activity performed by R (this activity being related to continuative and collective expenditures and efforts in innovation and R&D).

Cluster S has now an internal department (or sub-function) that generates only those ethereal intangible resources that are specific to its production process (replacing those intangibles that were formerly generated by Cluster R). These resources r_s are generated by the same production function as before (equation 2). Cluster S generates then two sub-outputs: a tangible sub-output s_y that is directly included in the bundle Y, and a soft intangible sub-output s_R that is passed-through to Cluster C. These outputs are generated by previous production functions (equations 4) and by the following function (5'):

$$s_R = \beta_s r_s \quad [5']$$

In this latter function, ethereal resources generated by R are set to zero (i.e. $r_t = 0$).

In turn, Cluster C now includes an R&D department (or sub-function) that generates those ethereal intangible resources that are specific to its activity (replacing those intangibles that were formerly generated by Cluster R). These resources r_C are generated by the previous production function (equation 2). As before, Cluster C generates the joint output c_Y – comprising three sub-outputs: c_T , c_A , c_R – by previous production functions (equations 6, 7 and 8) and by the following function (9’):

$$c_R = \beta_C(r_C) + \beta_{SR}s_R \quad [9']$$

In this latter function, ethereal resources generated by R are set to zero (i.e. $r_t = 0$).

Under separation, it is important to note that s_R is acquired by Cluster S at a negotiated transfer price p_S . This transaction results from separation of C and S that are now forced to internalise their respective functional activities of innovation and R&D previously accomplished by an autonomous Cluster R. Clusters C and S are then obliged to explicitly transact a knowledge transfer that enables C to exploit soft intangible resources generated by S.

2.6. Comparative Economic Institutional Analysis of telecommunication outcome under integration and separation regulatory regimes

Our two-step analysis of telecommunications industrial system allows a comparative assessment of its economic performance under alternative regulatory regimes. This performance is captured by efficient employment of resources to deliver an optimal level of utility for bundle Y. Both optimal performance and efficient employment of resources are determined by maximizing the generation of the bundle Y under constraints of costs of resources and functional activities.

As explained above, a better utility of bundle Y corresponds to an higher level of one or both elements of the bundle (c_Y, s_Y) . Consequently, the final level of the bundle (quantity/quality) will be driven either by the final price of the bundle or the cost of resources. These costs constitute the budget constraint for each producer.

Given the composite nature of bundle Y , this maximization process captures the trade-off between generation of new (or higher quality) telecommunication infrastructures and services (included in the bundle) and cost of resources and activities required to make them available to final users. By construction, optimal decision-making is concerned with production process that incurs decreasing returns to scale for all tangible and hard intangible resources. This process further incurs constant returns to scale for soft intangible resources and is confronted with ethereal resources (featured by constant returns to scale) that have neither reference pricing nor imputation costing. The latter resources provide then a positive externality that comes from the past and does not depend on current optimal decision-making. Concerning ethereal resources, for sake of simplicity, their continuative process is limited to one period with $\beta=1$, that is: $r^* = r^*_t = r^*_{t-1}$.

Optimal decision-making depends on the functional system of relationships as shaped by alternative regulatory regimes (Table III).

Table III. The input-output scheme under integration

$I = T, R$ $J = C, S$		S		R	C			Y
Input	X_{TJ}	s_Y			c_T			D_1
	A					c_A		D_2
	X_{RJ}			r_J				D_3
	r_{t-1}			r_t				
	r_J		s_R					
	r_t							
	s_R						c_R	
Ethereal output				r_t				R
Intermediate output			s_R	r_J	c_T	c_A	c_R	
output		s_Y			c_Y			$Y = D_1 + D_2 + D_3 + R$ $Y = s_Y + c_Y$

Under the case of integration, optimal decision-making is expressed by the following equation:

$$\underset{X_{IJ};A}{MAX} p_Y Y - \sum p_{X_{IJ}} X_{IJ} - p_A A \quad \text{with} \quad I = T, R \quad \text{and} \quad J = C, S$$

Solving the first-order-conditions, optimal level of resources is

$$X_{TJ}^* = \left(\frac{p_Y}{p_{X_{TJ}}} \right)^{\frac{1}{1-\alpha_{TJ}}} \quad [10]$$

$$A^* = \left(\frac{p_Y}{p_A} \right)^{\frac{1}{1-\alpha_A}} \quad [11]$$

$$X_{RS}^* = \left(\frac{p_Y}{p_{X_{RS}}} \right)^{\frac{1}{1-\alpha_{X_{RS}}}} (\beta_{SR} \beta_S)^{\frac{1}{1-\alpha_{X_{RS}}}} \quad [12]$$

$$X_{RC}^* = \left(\frac{p_Y}{p_{X_{RC}}} \right)^{\frac{1}{1-\alpha_{X_{RC}}}} (\beta_C)^{\frac{1}{1-\alpha_{X_{RC}}}} \quad [13]$$

All parameters α relate to the direct production process that transforms tangible and hard intangible inputs into a tangible output, while parameters β relate to the indirect production process that transforms soft intangible inputs in a soft intangible input for Cluster C and only subsequently in a tangible output (in equation 12, parameters β appear twice: this means that the production process is enveloped by both Clusters S and C, while parameters α indicate that the production process was started-up by Cluster R), or directly in a tangible output (see equation 13). For all optimal solutions, an increase of aggregate payments p_Y by final users for the bundle relative to the cost of an input $p_{X_{IJ}}$ (analytically, $\frac{p_Y}{p_{X_{IJ}}}$) implies a higher profitability of use of that input and an increased employment of it. Next section shall provide a numerical illustration of these mechanisms.

Functional structure of production of the bundle Y (analytically captured by equations from 1 to 9) decomposes the telecommunication outcome through respective contribution by four sets of resources (whose optimal amount is described by equations from 10 to 13) as follows:

$$Y = \sum_{m=1}^3 D_m + R \quad [14]$$

where:

$$D_1 = \sum_{J=S,C} \left[\frac{1}{\alpha_{TJ}} (X_{TJ}^*)^{\alpha_{TJ}} \right] \quad [I5]$$

$$D_2 = \frac{1}{\alpha_A} (A^*)^{\alpha_A} \quad [I6]$$

$$D_3 = \beta_C \frac{1}{\alpha_{X_{RC}}} (X_{RC}^*)^{\alpha_{X_{RC}}} + \beta_{SR} \beta_S \frac{1}{\alpha_{X_{RC}}} (X_{RC}^*)^{\alpha_{XS}} \quad [I7]$$

$$R \equiv c_Y + s_Y - \sum_{m=1}^3 D_m = \beta_C (r^*) + \beta_{SR} \beta_S (r^*) \quad [I8]$$

Therefore, equations 15, 16 and 17 capture an input-output economic analysis of production process⁵ (*à la Leontief*, who was inspired by Sraffa's seminal work), while equation 18 captures that production share which economic imputation of inputs to outputs cannot identify. This special element may be understood as the "residual" (*à la Solow*) of production process of telecommunication outcome. The residual captures what cannot be explained by attributing to each output the corresponding inputs used to generate them according to their specific productive process. This residual at industry level corresponds to the Solow's residual at macroeconomic level; it is generated by continuative and collective investments and efforts in innovation and R&D (analytically described by functional activity performed by Cluster R).

2.7. Analysis of telecommunication outcome under separation regime

Because of functional separation between S and C, optimal decision-making is solved through backward induction, starting from optimal decision-making by Cluster C, and consequently by Cluster S (see Table IV).

5 Generally speaking, an input-output analysis offers a structural view of industrial relationships, expressed in monetary terms, among different sectors of an economy throughout a certain period of time. Concerning telecommunications studies, Lee and Mokhtarian (2004) apply an input-output analysis to examine relationships between transportation and communication input intensities for US across multiple points in time. Plaut (1997) provides further references on input-output analyses of information and communications technology (ICT).

Table IV. The input-output scheme under separation

$I = T, R$ $J = C, S$		S			C				Y
Input	X_{TJ}	s_Y			c_T				D_1
	A					c_A			D_2
	X_{RJ}		r_S					r_C	D_3
	r_S			s_R					
	r_C								
	s_R						c_R		
Intermediate output			r_S	s_R	c_T	c_A	c_R	r_C	
output		s_Y			c_Y				$Y = D_1 + D_2 + D_3$ $Y = s_Y + c_Y$

This analysis further clarifies mutual relationship between these two Clusters. C uses resource s_R developed by S and transferred at a transfer price p_S . This payment results from negotiated (or regulated) arrangement establishing all the specific terms and conditions pertaining to the interaction between these now separated Clusters.

In particular, optimal decision-making by the Cluster C is

$$\underset{X_{RC}; X_{TC}; A}{MAX} p_Y c_Y - p_{X_{RC}} (X_{RC}) - p_{X_{TC}} X_{X_{TC}} - p_A A - p_S s_R$$

Solving the first-order conditions, optimal amount of resources for C is then:

$$X_{TC}^{**} = \left(\frac{p_Y}{p_{X_{TC}}} \right)^{\frac{1}{1-\alpha_{TC}}} \quad [19]$$

$$A^{**} = \left(\frac{p_Y}{p_A} \right)^{\frac{1}{1-\alpha_A}} \quad [20]$$

$$X_{RC}^{**} = \left(\frac{p_Y}{p_{X_{RC}}} \right)^{\frac{1}{1-\alpha_{X_{RC}}}} (\beta_C)^{\frac{1}{1-\alpha_{X_{RC}}}} \quad [21]$$

Equations (19), (20) and (21) are identical to equations (10), (11) and (13). Optimal amount of inputs used by Cluster C does not change. Nevertheless, its level of output is lower, because Cluster C cannot exploit any contribution of common ethereal resources that were formerly provided by Cluster R.

Optimal decision-making by the Cluster S is:

$$\underset{X_{RS}; X_{TS}}{MAX} p_Y s_Y + p_S s_R - p_{X_{RS}} (X_{RS}) - p_{X_{TS}} X_{TS}$$

Solving first-order conditions, optimal amount of inputs for S is

$$X_{TS}^{**} = \left(\frac{p_Y}{p_{X_{TS}}} \right)^{\frac{1}{1-\alpha_{TS}}} \quad [22]$$

$$X_{RS}^{**} = \left(\frac{p_S}{p_{X_{RS}}} \right)^{\frac{1}{1-\alpha_{X_{RS}}}} (\beta_S)^{\frac{1}{1-\alpha_{X_{RS}}}} \quad [23]$$

On this basis, functional structure of production of bundle Y decomposes the telecommunication outcome Y through respective contribution of three sets of resources as follows:

$$Y = \sum_{m=1}^3 D_m \quad [14']$$

First two terms (D_1 and D_2) are the same as in equations (15) and (16), whilst the third element (D_3) is given by the following equation:

$$D_3 = \beta_C \frac{1}{\alpha_{X_{RC}}} (X_{RC}^{**})^{\alpha_{X_{RC}}} + \beta_{SR} \beta_S \frac{1}{\alpha_{X_{RC}}} (X_{RC}^{**})^{\alpha_{X_{RC}}} \quad [17']$$

Next section shall provide a numerical and visual illustration of these mechanisms and their analytical results.

2.8. A numerical and graphical illustration

This section provides an illustration of model setup and its main results. In order to develop numerical computation, an explicit Demand Side is required to define an equilibrium price.

Let assume that there is a representative customer. This final user is interested in the consumption of the overall bundle Y . Costumer's choice is captured by the following standard utility function:

$$U = M + NY + a\frac{1}{2}Y^2 \quad [24]$$

with M and $N < 0$.

Inverse demand curve for the bundle is then:

$$p_Y = N - aY(d) \quad [25]$$

Following our comparative institutional economic analysis, Supply Side is defined by two scenarios related to integration and separation regulatory regimes. Simplified notation is provided by Table V.

Table V. A simplified classification of resources

	Inputs	Input contribute	Input cost
Tangibles and hard intangibles	$x = X_U$ and A	$f(*) = \frac{1}{\alpha}(x)^\alpha$ with $\alpha < 1$	$p_{X_U} = p_A = p_x$
Soft Intangibles	$r = r_j$	$g(*) = \beta(r)$ with $\beta \geq 1$	Imputed
Ethereal Intangibles	$r^* = r_{i-1}$	$h(*) = (r^*)$	Not computable

2.9. Integration regime

Accordingly, under integration regime, two sub-outputs are produced by Cluster S (equations 4 and 5):

$$\begin{aligned} s_Y &= \frac{1}{\alpha}(x)^\alpha \\ s_R &= \beta r + r^* \end{aligned} \quad [26]$$

Moreover, intermediate output produced by Cluster C (equation 6) becomes

$$c_Y = \frac{2}{\alpha}(x)^\alpha + c_R \quad [27]$$

where c_R , by equations (2 and 9) is

$$c_R = \beta r + r^* + \beta s_R = \left(\frac{\beta}{\alpha}(x_{RC})^\alpha + \beta r^* \right) + \left(\frac{\beta}{\alpha}(x_{RS})^\alpha + \beta r^* \right) \quad [28]$$

x_{Rj} (with $j = C, R$) captures here the amount of tangible inputs devoted to R&D.

Aggregating these sub-functions, the bundle Y may be rewritten as

$$Y = s_Y + c_Y = \frac{3}{\alpha}(x)^\varepsilon + \left(\frac{\beta}{\alpha}(x_{RC})^\alpha + \beta r^* \right) + \beta \left(\frac{\beta}{\alpha}(x_{RS})^\alpha + \beta r^* \right) \quad [29]$$

Optimal decision-making under integration regime becomes then:

$$\underset{x, x_{RC}, x_{RS}}{\text{Max}} \quad p_Y Y - p_X (x + x_{RC} + x_{RS}) \quad [30]$$

Solving F.O.Cs, optimal level of resources is

$$\begin{cases} x^* = 3 \left(\frac{p_Y}{p_X} \right)^{\frac{1}{1-\alpha}} \\ x_{RC}^* = \left(\beta^2 \frac{p_Y}{p_X} \right)^{\frac{1}{1-\alpha}} \\ x_{RS}^* = \left(\beta \frac{p_Y}{p_X} \right)^{\frac{1}{1-\alpha}} \end{cases}$$

Where x^* is the sum of optimal level of inputs as identified by equations (10) and (11), and x_R^* is the sum of optimal level of tangible resources devoted to R&D as identified by equations (12) and (13).

By substituting these solutions in the bundle function [29], optimal amount of supply becomes (equations 14-18):

$$Y = s_Y + c_Y = \frac{3}{\alpha}(x)^\alpha + \left(\frac{\beta}{\alpha} \left(\beta \frac{p_Y}{p_X} \right)^{\frac{\alpha}{1-\alpha}} + \beta \frac{\beta}{\alpha} \left(\beta^2 \frac{p_Y}{p_X} \right)^{\frac{\alpha}{1-\alpha}} \right) + (\beta r^*) + \beta r^*.$$

By computation, Supply function is then:

$$Y(s) = \frac{9}{\alpha} \left(\frac{p_Y}{p_X} \right)^{\frac{\alpha}{1-\alpha}} + \left(\frac{\beta}{\alpha} \left(\frac{p_Y}{p_X} \right)^{\frac{\alpha}{1-\alpha}} + \left((\beta)^{\frac{\alpha}{1-\alpha}} + \beta (\beta^2)^{\frac{\alpha}{1-\alpha}} \right) \right) + \beta(1 + \beta)r^*.$$

Table VI summarises this input-output analysis under integration regime

Table VI. Input-output analysis under integration

	Clusters	Inputs	Intermediate output	Output	output
Tangibles and hard intangibles used to produce the final output	S	$x^* = 3 \left(\frac{p_y}{p_x} \right)^{\frac{1}{1-\alpha}}$		s_y	$3 \frac{\alpha}{\alpha} \left(\frac{p_y}{p_x} \right)^{\frac{\alpha}{1-\alpha}}$
	C		c_A	c_y	$6 \frac{\alpha}{\alpha} \left(\frac{p_y}{p_x} \right)^{\frac{\alpha}{1-\alpha}}$
	A		c_T		
Tangibles used to produce the Soft Intangibles	R	$x_R^* = \left(\frac{p_y}{p_x} \right)^{\frac{1}{1-\alpha}} \left((\beta)^{\frac{1}{1-\alpha}} + (\beta^2)^{\frac{1}{1-\alpha}} \right)$	$r_j + r^*$	s_R	$(1+\beta) \left(\frac{\beta}{\alpha} \left(\frac{p_y}{p_x} \right)^{\frac{\alpha}{1-\alpha}} (\beta)^{\frac{1}{1-\alpha}} \right)$
				c_R	$(1+\beta) \left(\frac{\beta}{\alpha} \left(\frac{p_y}{p_x} \right)^{\frac{\alpha}{1-\alpha}} (\beta^2)^{\frac{1}{1-\alpha}} \right)$
					$\beta(1+\beta)r^*$

Figure 4 shows Demand and Supply functions for assigned parameters:

Figure 4. Demand and Supply functions with $\alpha=0.7, \beta=1, p_x=1, r^*=10, N=400, a=\frac{1}{50}$.

Table VII shows a numerical input-output analysis for assigned parameters:

Table VII. The input-output scheme under integration

	Clusters	Inputs & costs ($p_x = 1$)	Sub-output		output		Revenue ($p_Y = 3$)
x^*	S	116.82			s_Y	55.63	166.89
	C			c_A	c_Y	111.26	333.78
	A			c_T			
x_R^*	R	92.50	s_R	18.54		55.62	
			c_R	18.54		55.62	
r^*			Input 10 (zero cost)			20	60
Total Revenue							671.91
Total Costs		-209.32					-209.32
Profits							462.59

2.10. Separation regime

Under separation regime, optimal decision-making of Clusters C and S become:

$$\begin{cases} \max_{x, x_R} [p_Y c_Y - p_x (x + x_R) - p_S s_R] \\ \max_{x, x_R} [p_Y s_Y - p_x (x + x_R) + p_S s_R] \end{cases}$$

Solving the F.O.Cs, optimal level of resources (equations 19-23) is

$$x^* = \begin{cases} 2 \left(\frac{p_Y}{p_x} \right)^{\frac{1}{1-\alpha}}, & \text{Cluster C} \\ \left(\frac{p_Y}{p_x} \right)^{\frac{1}{1-\alpha}}, & \text{Cluster S} \end{cases} \quad \text{and} \quad x_R^* = \begin{cases} \left(\frac{p_Y}{p_x} \right)^{\frac{1}{1-\alpha}} (\beta)^{\frac{1}{1-\alpha}}, & \text{Cluster C} \\ \left(\frac{p_S}{p_x} \right)^{\frac{1}{1-\alpha}} (\beta)^{\frac{1}{1-\alpha}}, & \text{Cluster S} \end{cases}$$

Optimal amount of supply becomes (equation 14')

$$Y(s) = \frac{9}{\alpha} \left(\frac{p_Y}{p_x} \right)^{\frac{\alpha}{1-\alpha}} + \left(\frac{\beta}{\alpha} \left(\frac{p_Y}{p_x} \right)^{\frac{\alpha}{1-\alpha}} (\beta)^{\frac{\alpha}{1-\alpha}} \right) + \left(\frac{\beta}{\alpha} \left(\frac{p_S}{p_x} \right)^{\frac{\alpha}{1-\alpha}} (\beta^2)^{\frac{\alpha}{1-\alpha}} \right).$$

Figure 5 shows Demand and Supply functions for assigned parameters:

Figure 5. Demand and Supply functions for increasing values of $p(y)$ with

$$\alpha = 0.7, \beta = 1, p_x = 1, r^* = 10, N = 400, a = \frac{1}{50}.$$

Under separation regime, relative bargaining power of Clusters S and C (captured by transfer price p) reshapes optimal delivery (by C) and consumption (by S) of tangible inputs devoted to R&D activities. To visualise this result, Figures 5 and 6 show two main effects: (i) A direct effect generated by the absence of ethereal resources, which involves a geometrical translation to the right of supply function by $\beta(1+\beta)r^*$ (i.e. Bundle's higher price and lower quantity/quality due to missing contribution by ethereal resources); (ii) An indirect effect generated by different bargaining power of Clusters, which involves a geometrical change in the shape of Supply curve (i.e. higher the bargaining power of Cluster C, lower the level of total investment in R&D by both Clusters S and C, and consequently lower the quantity/quality of bundle Y).

Figure 6. Investments in R&D under integration and under separation. Under separation the bold line refers to the Cluster C and the dash lines refer to various degrees of bargaining power by C (i.e. higher power, lower $p(s)$)

Table VIII further illustrates our numerical input-output analysis under separation regime for assigned parameters.

Table VIII. The input-output scheme under separation regime

	Clusters	Inputs & costs ($p_x = 1$)	Intermediate output		Output ($p_S = 0.5p_Y$) ($p_Y = 3$)		Revenue Cluster S	Revenue Cluster C
x^*	S	38.94			s_Y	55.63	166.89	
	C	77.88		c_A	c_Y	111.26		333.78
	A			c_T				
x_R^*	R(S)	3.86	$r_J + r^*$	s_R		3.68	5.52	11.04
	R(C)	38.94		c_R		18.54		55.62
r^*		0				0	0	0
Revenue							172.41	389.4
Costs (Cluster S)		-42.8					-42.8	
Costs (Cluster C)		-116.82				-5.52		-122.34
Profits							129.61	267.06

Tables VII and VIII are computed with the same equilibrium price in both regimes. Under separation regime, we further assume that Cluster C has a bargaining power such that the price p_S is settled to $\frac{1}{2}$ of the price p for the whole bundle.⁶

By comparing both I/O tables, total profit under integration is greater than under separation (462.59 against $129.61 + 267.06 = 396.67$). Furthermore, by assuming that total profit is equally shared between Clusters S and R under the integration regime, it is straightforward that Cluster C (S) receives a lower (higher) share under separation regime. Accordingly, the Cluster with higher bargaining power is able to extract higher profit from negotiation with the other Cluster, even though this bargained equilibrium implies at the contractual level a worst situation for the entire economy (lower quantity/quality of the joint bundle that is delivered to customers).

⁶ This assumption is equivalent to assume that p_S is higher than the marginal cost of inputs employed by Cluster S. This latter cost is assumed equal to one in our numerical exercise (see Table VIII).

3. IMPLICATIONS AND RECOMMENDATIONS FOR REGULATION OF TELECOMMUNICATIONS INDUSTRY

3.1. Implications of our comparative institutional economic analysis of alternative regulatory regimes of separation and integration

A comparative assessment of both regulatory designs may be derived by comparing outcome Y under regimes of integration and separation. It is straightforward that equation (22) is identical to equation (10), although output is lower because Cluster S cannot longer exploit the contribution of common ethereal resources that were formerly provided by Cluster R. In particular, because ethereal resources generated by joint research have disappeared (i.e. $r_t = 0$), then $c_Y + s_Y - \sum_{m=1}^3 D_m = 0$ and consequently $R = 0$: no residual appears. This analytical result is resumed by the following lemma:

Lemma *Existence of an autonomous R&D Cluster – capable to assure generic and specific R&D and innovation, including continued search, development and collective implementation of innovative results – implies generation of ethereal intangible resources which contribute to enhance the joint performance (Y) of the telecommunications system.*

This assumption is strictly linked to the definition of ethereal resources and the consequent impossibility to attribute either a market price or an imputed cost to them. For sake of simplicity, we assume that these resources disappear under separation regime. The same result holds when these resources do not disappear (i.e. when their amount is zero), because no remuneration can be settled for them in the contractual arrangement between C and S, S being unable to settle their remuneration with C.

Furthermore, critical differences emerge between equation (23) and equation (12). These differences justify the following proposition:

Proposition 1: *The loss of an autonomous R&D Cluster (lemma 1) under separation, with its partial replacement by distinct R&D departments of separated Clusters, implies a lower optimal performance of the bundle Y due to a **deploying effect** and a **bargaining effect**.*

Corollary 1: ***Deploying effect** is strictly linked to Lemma 1 and the characteristics of ethereal resources. Our model shows that this effect is greater than zero and consequently that functional integration is strictly superior to functional separation.*

Deploying effect is captured by equation (18).

Corollary 2: ***Bargaining effect** is generated by the respective bargaining power by Clusters. Our economic analysis shows that indirect effect is greater than zero.*

Bargaining effect is captured by differences between equation (17) and equation (17').

Proof of proposition 1: Existence of ethereal intangible resources (which is described by R) implies higher level of production of telecommunications outcome Y. The deploying effect may be understood as the impossibility to deploy the residual of the overall performance of the system (this residual consists of the output share that is not explained after that each output component of the joint bundle has been connected to the contribution of involved inputs). Comparison between optimal performances Y under alternative regimes shows that production is always greater under integration regime. This implies that integrated solution is strictly superior to separation, providing a First Best Solution.

Previous section has provided a numerical illustration of this proposition.

Further differences emerge between equation (17) and equation (17'), justifying the following proposition:

Proposition 2: *Under separation, a transaction between S and C is required to arrange the delivery of intangible output between S and C. If and only if Cluster S is able to appropriate all the extra-performance of the bundle generated by provision of its intangible output, the telecommunications system may generate a*

Second Best Solution where $p_S = p_Y \beta_{SR}$ (implying that identity between equation (17) and equation (17')).

Proof of proposition 2: By comparing equation (23) and equation (12), three possible solutions exist relative to the balance between the transfer price p_S paid by C and the actual contribution of related input to the overall performance of the bundle Y:

- The first solution is $p_S > p_Y \beta_{SR}$. This means that the transfer price of the (whole of) intangible resource(s) that Cluster C acquires from Cluster S is higher than the actual contribution of that resource(s) to the overall performance of the bundle. This would imply that C should pay for that resource more than the aggregate extra-revenue that may be extracted from customers by exploiting the resource in its production function. It is straightforward that the demand by Cluster C for the input s_R will be zero in this case. This scenario cannot occur under optimal decision-making by C;
- The second solution is $p_S = p_Y \beta_{SR}$. This means that the transfer price is equal to the actual contribution of the resource to the overall performance of the bundle. This would imply that C pays for that resource exactly the aggregate extra-revenue that may be extracted from the customers;
- The third solution is $p_S < p_Y \beta_{SR}$. This means that the transfer price is less than the actual contribution of the resource to the overall performance of the bundle. This would imply that C pays for that resource less than the aggregate extra-revenue from the customers. This has two main consequences: from one hand, C is enabled to appropriate a quasi-rent by controlling access to final customers; from another hand, the optimal amount of resource provided by Cluster S is lower than in the second solution, with detrimental effects on the overall performance of the system as a whole.

Corollary 4: If the transaction between S and C is achieved under perfect competitive conditions (implying that the transacted payment of output generated by S for C tends to its marginal cost, $p_S \rightarrow p_{X_{RS}}$) and $p_{X_{RS}} < p_Y \beta_{SR}$, then the telecommunications system will generate a Third Best Solution, where $p_Y \beta_{SR} > p_S > p_{X_{RS}}$ (i.e. the difference between equation (17) and equation (17') is positive).

As discussed above, only if $p_S = p_Y \beta_{SR}$, the equation (17') is equal to the equation (17). Otherwise, whenever $p_S < p_Y \beta_{SR}$, equation (17') is lower than equation (17): optimal performance of the bundle Y is consequently lower.

3.2. Recommendations for regulatory frameworks and policies concerned with access, costing and pricing

This comparative analysis of both paradigmatic regimes provides some recommendations for regulation of access, costing and pricing of the telecommunication system. Our analysis raises major concerns with forcing separation by regulatory design. The first concern regards absence of common and continuative ethereal resources generated by the functional activity of innovation and R&D (Cluster R). This absence leads to a second-best solution relatively to first best solution provided by functional integration. Furthermore, although other benefits from separation are expected to compensate this net loss of commonalities in innovation and R&D, another potential shortcoming arises from mutual relationship between S and C under separation regime. If regulatory bodies attempt to force S to provide a universal commodity under the same competitive terms and conditions for every operators of C, this attempt may engender a critical underinvestment in specific resources by S. Competitive pricing imposed by regulation may allow C to pay only for the costs incurred by S, while C may then appropriate all extra-revenue generated by the joint performance of C and S (rent extraction). This implies an inefficient profit-sharing arrangement between C and S. Operators of infrastructure intermediation S would then be penalised relative to operators of content intermediation C. On the contrary, any efficient solution should allow S to share the extra-profit generated by the joint performance of S and C on a satisfying basis. In particular, the transfer price should be higher than a mere refunding of costs incurred for tangible resources; it should include an appropriate quota of the contribution of S to the overall performance of the joint telecommunication outcome.⁷ These profit-sharing schemes may be left to the contractual arrangements between operators under appropriate regulatory frameworks. According to Laffont and Tirole

7 The analysis of appropriate costing and pricing arrangements to settle this quota is left to a further exercise.

(2000, p. xv), “marginal-cost pricing for all services is not viable in telecom industries (at least in certain important segments involving large joint and common costs), so the relevant benchmark requires some mark-ups. Allowing at least some price discrimination can therefore reduce the pricing distortion. Price discrimination may also be the prerequisite for the viability of certain investments”. These scholars suggest here allowing departures from competitive pricing when large joint and common costs are involved. Our approach relates these commonalities to two main features of regulated industries: (i) common innovation and R&D processes, and (ii) the public interest objectives of universal accessibility to service and quality improvements.

These conditional departures from competitive pricing should be further submitted to standardised *accounting structures* that factually identify and measure underlying resources and activities for purpose of costing and pricing; otherwise, any regulatory determination of this purpose would result highly discretionary (Laffont and Tirole, 2000, p. 148). According to our framework of analysis, operators and regulators need to properly account for both hard intangibles that have market prices of reference, and soft (and ethereal) intangibles that factually have not. From this perspective, a stock method of accounting for intangibles results to be too narrow, because of its focus on hard intangibles alone. A flow method of accounting should be preferred; this latter method tracks the cumulated flow of direct and indirect investments in innovation and R&D, allowing their conventional imputation within and between operators. This cost-based representation of soft intangible resources may be further integrated by some appreciation of ethereal intangible resources that are fundamental but beyond accounting measurement through imputed cost (cf. Biondi and Reberioux, 2012 for further analysis).

CONCLUSION

In the recent decades, new regulatory policies of telecommunications industry have been purporting to disband formerly functionally-integrated monopolies owned by the state. The basic idea consists in a separation by regulatory design between operators of telecommunication

infrastructures (infrastructure providers) and providers of information services over them (content providers). In fact, these policies need to balance competitive conditions with promotion of innovation and development of telecommunication products, services and infrastructures. Our paper has developed an input-output analysis of telecommunication industrial system that connects the producers of contents (who originate information and communication) to final consumers (who receive them). Accordingly, telecommunications industry is jointly constituted by four functional Clusters which exploit four kinds of tangible and intangible resources (this framework is generic and may be applied to other infrastructures-based industries) under distinctive regulatory regimes of functional integration and separation. On this basis, our comparative institutional economic analysis casts doubts on functional regulation by showing two inefficient shortcomings: first, the net loss of shared and continuative innovation and R&D; second, the underinvestment in infrastructures development and innovation whenever the infrastructure provision is treated as the arm's length provision of a universal commodity under strictly competitive terms and conditions. In contrast, our analysis recommends the regulatory allowance of fair profit-sharing arrangements between infrastructure providers and content providers over limited periods of time, coupled with standardised accounting structures for costing and pricing that should comprise the whole range of intangible resources deployed by telecommunications industry, not only those that have identifiable market prices of reference.

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