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The need for coherence between institutions and technology in liberalized infrastructures: the case of network unbundling in electricity and railways

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This paper addresses the question of the coherence in the infrastructures. More precisely, it examines the articulation between technical and institutional coherence. It assumes that a certain degree of such coherence is necessary for infrastructures (network industries) not only to properly function, but moreover to be both economically and socially performing. The paper takes the current unbundling of the electricity and the railways sectors as cases so as to analyze whether and how the dynamics of deregulation (liberalization) leads to such incoherence. It is therefore grounded in organizational behaviour and institutional analysis and focuses on the strategies of the actors in a liberalized environment. The paper is therefore primarily conceptual in nature, as it seeks to frame the dynamics of the liberalizing network industries in terms of a co-evolution between technology and institutions.

Table of content

INTRODUCTION

Liberalization in infrastructures is focused on institutional changes, such as unbundling, deregulation, privatization, public-private partnerships, asymmetric regulation, and other practices related to market structure. The idea is to obtain efficiencies and quality improvements, basically by means of introducing a competitive economic market structure and private sector oriented institutional regimes. In this approach, technology is mainly considered as being a constant. The technical system, it was assumed, would operate more efficiently because of a market-oriented approach. Economically oriented actors would create new contractual arrangements on a voluntary basis, if required. In some extreme cases, a sector-specific regulator might “support” this process. Institutional innovation was to create a market, and technology was either a product or an instrument of such a market, but considered as a system whose function constituted a necessary condition for the market.

This paper questions this very assumption, namely that (1) institutional changes are sufficient to create a market in the infrastructures, that (2) technology would remain at a stable and neutral condition, so as to support the functioning of the market, and that (3) sector-specific regulation would be sufficient to make these market-type arrangements work. As a matter of fact, it may well be that, in certain cases, technology goes against markets, or at least does not automatically support liberalization. This paper builds on the co-evolution between technology and institutions literature and applies it to the infrastructures, saying that there is a need for coherence between both in order to safeguard a satisfactory technical functioning, which in turn will determine economic and social performance. We focus on one specific element of the liberalization of infrastructures, i.e., network unbundling, as this was the core idea of institutional change so as to create markets in infrastructures.

From an economic perspective networks are traditionally considered a focal point of regulation in infrastructure-bounded markets. Networks are unique and essential facilities with characteristics of a natural monopoly. This implies that even in liberalized markets, physical networks represent monopolistic facilities that fundamentally distort market functioning. In order to prevent undesirable opportunistic behavior by network operators – i.e., gaining advantage by obstructing third party access – sector-specific regulation requires that network operations be separated from other core activities such as trade, metering, and sales. These associated commercial activities are allowed to compete, whereas the networks have to function as regulated monopolistic activities. This separation between the networks and the production/trade/metering/sales of is often referred to as “unbundling”.

However, network unbundling is an institutional change before being a technical one. As a matter of fact, and from a technical perspective, network unbundling might pose considerable problems for the technical functioning of the network operations. In the electricity sector and in rail transport, the technical operation of networks is indivisibly connected to the so-called commercial activities of – for instance – electricity production and trade, or the transport of goods and services to different destinations in the railway network. In the electricity sector the network operator needs to physically balance demand and supply, even in liberalized markets. Electricity production and transport are, to a certain degree, technical substitutes that can equally be utilized to balance demand and supply. In the railroad sector the operation, monitoring and maintenance of the tracks can hardly be technically separated form each other. In these cases, unbundling creates institutional barriers that obstruct the technical functioning of the system. The unbundling of the railroad sector in the UK resulted in serious technical malfunctioning of the system that caused several deadly accidents. The blackouts in the electricity system are symptoms for the difficult technical coordination of the unbundled commercial activities.

The question therefore is whether network unbundling as an institutional change will obstruct the very technical functioning of the electricity and rail transport sectors, and whether the dynamics triggered by such unbundling will trigger a dynamics that is beneficial or detrimental to the function of the technical system. Conceptually, we will approach this question from an organizational and an institutional perspective. In other words, we will try to understand what network unbundling, as an institutional change, triggers in terms of actors (strategic) behavior, and how such behavior affects the entire technical system in both the electricity and the railway sector in terms of economic, social, and technical performance.

The paper is therefore structured as follows: in a second chapter, we will recall our conceptual framework, i.e., the idea of a co-evolution between institutions and technology. Our hypothesis is that there needs to be a certain degree of coherence between institutions and technology in order to safeguard the satisfactory functioning of infrastructure sectors. The next two chapters will focus on the degree of coherence between institutions and technology in the unbundled electricity and the railways sectors. In particular, we compare the situations in both sectors before and after unbundling, both in technical and in institutional terms. Both will highlight, in particular, which actors emerge and play a role after unbundling. Chapter 5 will then identify these actors' (strategic) behavior and dynamics in both sectors. In particular, it will show the relevant actors' strategies both vis-à-vis the other actors in the (now much broader) industry, but also their respective strategies vis-à-vis the technical infrastructure, in particular vis-à-vis technological innovation. Indeed, the whole idea of unbundling is to create competition among the users of the network, thus introducing a significant change in behavior among them. In the conclusion, then, we will assess how these actors' strategies and dynamics are likely to affect the performance of the electricity and the railways sectors in economic, social, and technical terms.

1. TECHNOLOGICAL AND INSTITUTIONAL COORDINATION IN INFRASTRUCTURES

As said above, we work with the assumption that there needs to be a certain coherence between the technical and the institutional coordination for the network industries (infrastructures) to function and moreover to perform both in economic and social terms. This assumption, in turn, is grounded in the literature on the co-evolution between technology and institutions, a literature, which however so far has not been focused on the network industries. The following figure summarizes our assumption.

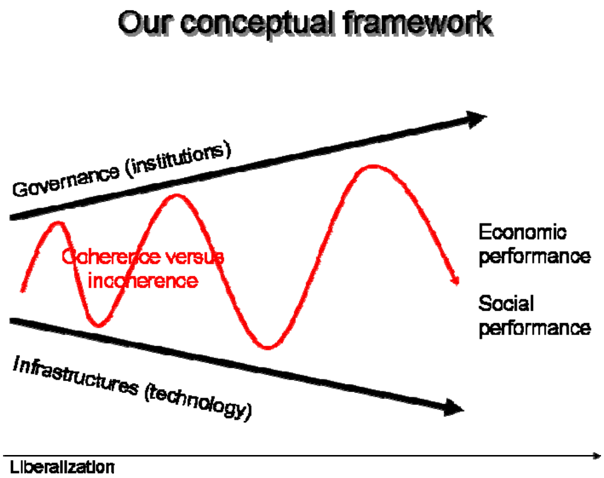

Figure 1: Our broad conceptual framework.

On the basis of this broader conceptual framework, we now explore the possible relationship between technological and institutional coordination of infrastructures on the one hand and the performance of these infrastructures on the other. Our line of argument is illustrated in figure No.2.

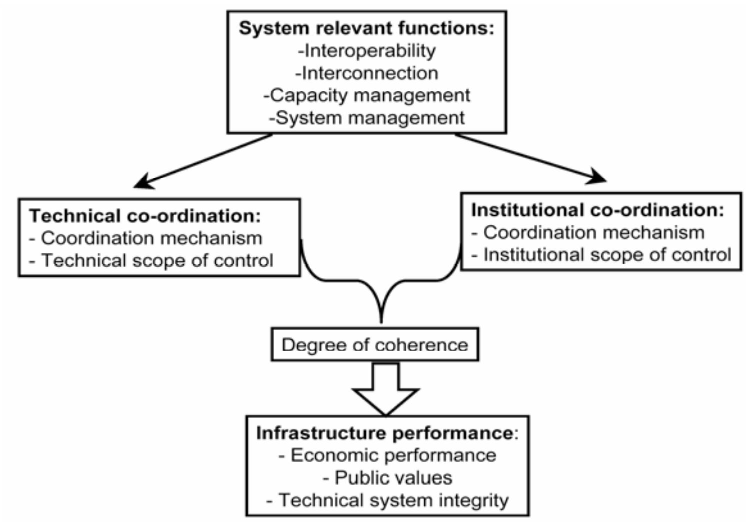

Figure 2: The relationship between technology, institutions, and performance of infrastructures.

At the most basic level, we start with the definition of four basics functions that need to be guaranteed in order to safeguard the functioning of infrastructure related networks. These basic functions need to be supported technically as well as institutionally by some governance mechanism. We will argue in the following paragraph that there needs to be a certain degree of coherence between this technical and institutional coordination in order to satisfy different aspects of infrastructure performance, i.e. economic performance, public values and technical system integrity. We will summarize our argument here only very briefly. For a more detailed discussion we refer to our earlier work.[1]

[1] Finger et. Al. 2005.

More precisely, we argue that in the network industries four basic system-relevant functions need to be performed so that they properly function. The following functions are related to the operation of networks that enable the complementarity between the nodes and links in infrastructures. Interconnection deals with the physical linkages of different networks that perform similar or complementary tasks (e.g., Economides, 1996). Typical examples include the interconnection of different telecom networks, railroad tracks or electricity systems. Interoperability is realized if mutual interactions between network elements are enabled in order to facilitate systems' complementarity. For example, in the railroad sector, the specification of the tracks needs to be aligned with the needs of the locomotives. Interoperability defines the technical and institutional conditions under which infrastructure networks can be utilized. Capacity management is necessary in order to allocate scarce resources with the networks. Depending on the time scale on which this capacity allocation occurs, different aspects of capacity management can be distinguished[2]: real-time operational, like the dispatching of the electricity system, tactical (for instance maintenance scheduling) or long term strategic (building of new rail tracks). System management pertains to the question of how the overall system (e.g., the flow between the various nodes and links) is being managed and how the quality of service is safeguarded.

On a very basic level, three different coordination mechanisms can be identified; i.e. centralized, decentralized and peer-to-peer (e.g., Powell, 1996; Thompson, 1996), [3] as summarized in table No.1. This simple distinction is based on the level of decision-making. A centralized system uses a top-down approach, in which some centralized authority controls all major systems elements or operations. In a technical system, there might be an operator that controls the entire production process. The equivalent institutional arrangement is for instance a centrally planned economy.

In a decentralized system, decision-making is distributed throughout numerous agents. System coordination is realized by certain institutional arrangements, but without any active planning or direct intervention. A very famous example in this respect is the institutional coordination of competitive markets. All actors compete against each other and search their own profit. The price mechanism is the invisible hand that co-ordinates the system in a way that markets are cleared and social welfare is optimized. A likewise technical system is for instance road transportation. Participants enter this infrastructure based on individual preferences and decisions. The transport service is based on the available capacity at the specific moment of use. The coordination of the functioning of the entire road transport system is effectuated by traffic rules that govern the behavior of individual users. Besides, capacity problems are solved through queuing and temporary storage, which is commonly known as traffic congestion.

Under the conditions of peer-to-peer coordination, self-selected agents mutually co-ordinate their activities based on bilateral agreements. A system might be coordinated through bilateral arrangements between different agents. Bilateral contracts are typical institutional arrangements that fit this category. Actors agree on a specific exchange of goods or services that fit their individual needs. In the Internet for instance, peer-to-peer agreements are established for the mutual exchange of electronic traffic. In air transport there are alliances of carriers that mutually coordinate their services

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2 Ten Heuvelhof et. al. 2003.

3 These authors use the notion of network instead of peer-to-peer. We chose for this latter notion in order to avoid confusion with different definitions of the notion of networks.

in order to gain competitive advantages. Often this includes also a mutual technical coordination of the corresponding technical networks.

Table 3: Different types of coordination mechanisms.

Coordination mechanism	Technical coordination	Institutional coordination
Centralized	Centralized control: top-down	Planned economy
Decentralized	Distributed control bottom-up	Market economy; classical contracting
Peer to peer	Peer-to-peer control	Relational contracting

Taking these three types of coordination as a point of reference, it is now possible to define two aspects of coherence:

- Comparable technical and institutional coordination mechanisms;
- Comparable scope of control. We consider the scope of technical and institutional coordination as coherent if they are related to comparable system boundaries. In other words, technical and institutional coordination is related to the same entity but with respect to different harmonization needs.

In line with the idea of a co-evolution between institutions and technology (e.g., Dosi, 1982; North, 1990; Perez, 2002; Saviotti, 1996; Soete, 1985; van Tunzelmann, 2003), we argue that there is an interrelation between the technical and institutional coordination of infrastructures. The four major network functions – e.g., interconnection, interoperability, capacity management, and system management – are pivotal for enabling the functioning of infrastructures and taking profit from the complementarities between the systems' nodes and links. A comparable institutional and technological coordination is necessary to enable these functions to support the production of goods and services throughout the infrastructure. The more these coordination mechanisms are coherent, the better infrastructures perform. We illustrate our argument in the next two chapters by using the examples of electricity and railways unbundling.

2. THE ELECTRICITY SECTOR BEFORE AND AFTER UNBUNDLING

Traditionally the electricity sector has been strongly vertically integrated between production, high-voltage long-distance transmission, low-voltage distribution, and sales. One single firm might have integrated all activities within their own scope of control, typically organized as a regional monopoly. In other cases, production and transmission was integrated, next to distribution and supply. The electricity sector was largely institutionalized along with the technical system boundaries of the respective networks. This changed quite fundamentally after the liberalization. From an institutional perspective, liberalization required unbundling of the value chain into independent entities. Since network related activities are considered natural monopolies, they could not be exposed to competitive markets. Roughly electricity production and supply are perceived as commercial activities, whereas transmission and distribution are regulated monopolies. Figure 4 depicts the structure of the electricity value chain before and after liberalization.

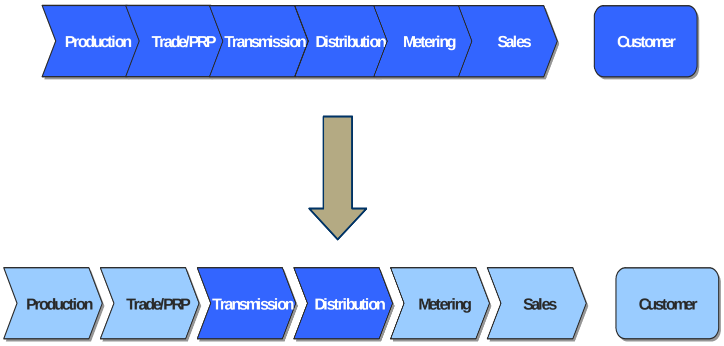

Figure 4: The electricity value chain before and after liberalization (Fens, 2005).

From a technical point of view the activities within the value chain are strongly interrelated, before as well as after the liberalization. There was no major technical change in this respect. Electricity is generated at the production unit. It is then traded on the wholesale market and transported via the transmission unit (highways for electricity) and the distribution unit (regional and local networks for electricity). The electricity is metered during transport not only for billing purposes but also to ensure proper management of the physical flow of electricity in the entire value chain. Finally, in the sales unit the physical flow ends with delivery to the end customer according to the contracts agreed upon. Technically the electricity sector has to be managed as one single integrated system. The flow of electricity cannot be directed between specific economic actors. It rather depends on the specific physical circumstances of the electricity system how and whether specific physical transactions are possible. In order to allow a continuous availability of high quality electricity, all parts of the system from production to supply have to be technically balanced at each moment of time. Transmission and distribution systems operators are in charge for this technical balancing of the electricity network. From an economic perspective this technical system management is a pure collective good that cannot be provided by market allocation.

2.1 Characterization of system relevant functions

Interoperability is realized through a close standardization of technical processes and requirements with respect to the quality of electricity that is delivered throughout the system. Among others, the systems voltage is determined within certain margins, the amplitudes of the alternate currents are synchronized and there is a central authority that oversees the standards and the systems operation. In Europe for example, UCTE[4] coordinates the operation and development of the electricity transmission network between some 23 countries. This organization is active for more than 50 years. Coordination of transmission activities is necessary because the electricity network technically functions as one large system, in which the flow of electric currents cannot be directed. According to physical laws, electricity flows are determined by the differences of electric resistance within the system. Between different systems, electricity cannot be exchanged without additional technical measures. In principle these electricity systems operate independently from each other.

[4] Union for the Coordination of Transmission of Electricity, www.ucte.org

Interconnection appears within the boundaries and conditions of the above mentioned electricity systems as physical links between different regional or national networks. Interconnection appears at two different levels. First, between different high-voltage transmission networks, which is overseen by the Transmission system operators (TSO's). Second, between the transmission network and distribution networks. These interconnections are coordinated between the TSO's and the Distribution Network Operators (DSO's).

Capacity management is achieved as follows. .At the strategic level terms and conditions for network access are documented in a so-called network code. On the tactical level the quality standards are largely given through the regulations of the international electricity system. Operational capacity management is usually handled at the level of the transmission system operator. In liberalized electricity markets, suppliers of electric power as well as traders (who represent the customers) have to notify the TSO of their supply or demand 24 hours in advance for each period of 30 minutes. The TSO is able to calculate the technical opportunities of the system to meet these requirements. If technically necessary, rearrangements have to be made. Since electricity cannot be stored, the balancing of demand and supply is a very challenging task. The physical limitations of networks and the availability of production capacity has to be adjusted against a technically uncontrollable demand for electricity. Usually there is no demand side management involved in the operation of electricity systems.

In the case of the electricity sector, *system management* deals with the continuous technical balancing of the production and use of electricity as well as safeguarding the quality of service. Load management is vital. It includes the provision of back-up capacity for the case of emergency or unexpected increases in demand. Also the technical quality needs to be maintained, for example in terms of frequency, reactive energy, and voltage. Commonly these tasks are directed to the system operator.

2.2 Determination of the degree of coherence between technical and institutional coordination

The technical coordination can be best characterized as centralized top-down control. Electricity systems like the UCTE are governed by a central administered and controlled regime of norms and standards. The regional or national system operators have very significant technical tasks with respect to interconnection, capacity management and system management. With respect to the technical scope of control, certainly the boundaries of the electricity system describe the ultimate limits. Within these boundaries certain subsystems can be acknowledged. On the high voltage transmission network level, there are various interconnected regional or national networks. On the low voltage level there are many distribution networks that have no major technical functions expect the transformation and transport of electricity to the final customer.

In liberalized markets, the institutional coordination ideally fits the decentralized coordination mechanism with bottom-up control. Consumers and producers take their allocation decisions based on individual preferences, needs and profitability. There are at best insufficient or even absent pricing signals with respect to the physical network capacity. Network complementarities are not adequately supported by pricing signals. Actors just behave as if the network is a 'copper plate' that allows all kinds of economic transactions without any physical restrictions. The scope of the institutional coordination of is not per se limited by the technical boundaries. Well functioning markets have the tendency for international expansion and ultimately globalization. Nowadays differences in national regulation establish barriers for trade and determine in this way the institutional boundaries of the electricity market.

Prior to liberalization the institutional coordination was quite different. There was a high degree of vertical integration of electricity firms, as indicated in the value chain in figure 3. These firms functioned as integrated regional monopolies and had an economic incentive to capitalize on the network complementarities. Under these conditions the institutional coordination was more centralized with top-down control. The scope of institutional control was very much in line with the scope of technical control.

It can be concluded that prior to liberalization there was a high degree of coherence between the institutional and technical coordination of the sectors activities. Liberalization resulted in a novel institutional structure of the sector, leaving the technical coordination unchanged. Consequently, technical and institutional coordination are incoherent.

2.3 Analysis of system performance

According to our hypothesis we would expect that the performance of the electricity sector is deteriorating after liberalization. We will shortly reflect on this hypothesis with respect to the three performance criteria we earlier defined.

With respect to the economic performance there are indications that price efficiency increased. For example in the EU the price for electricity seemed to have declined on average.[5] Without any further research it is very difficult to provide evidence whether dynamic efficiency or system efficiency is improved. Considering the innovativeness it should be noted that in the past years quite some new technologies reached the market. Examples include small-scale electricity production, clean technologies, metering and control. On the other hand, there have been quite some noticeable economic disasters in the electricity sector, like for instance the Enron bankruptcy and the California energy crises. Based on this very superficial approach, it can be stated that at there is at least no hard evidence for the validity of our hypothesis with respect to the economic performance.

Safeguarding public values is a growing concern. Security of supply is high on the political agenda of many countries, even as environmental sustainability of electricity production. Universal service obligations are an important issue for example with respect to the accessibility to electric power. Also the affordability of electric power is an issue, which is recently amplified by the raising oil and gas prices. The reliability seems to decline, since energy firms try to operate closer to the technical system capacity in order to economize their production processes. There is genuine concern whether the market mechanism provides sufficient incentives to build new electric power capacity, even for off-peak or emergency purposes. Prior to liberalization, these issues were far less prominent.

The integrity of the technical system is not supported by the institutional arrangements of liberalized markets. The above-mentioned energy outages in California, but also in Europe indicate that there

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5 Kema 2005.

might be a problem in this respect. Systems seem to be less robust, among others as a consequence of declining reserve margins in production and networks.

Based on this very rough and certainly incomplete analysis a differentiated picture about the performance of the electricity sector after liberalization arises. While there might be some improvements with respect to price efficiency and innovativeness, there are growing concerns with respect to the realization of public values and the safeguarding of the technical system integrity. These latter are certainly new problems. However, prior to liberalization economic performance might have been weak, but the other performance criteria might have been stronger. Without any further research the trade-off between both is difficult to make. This case demonstrates that after liberalization the technical coordination is a serious problem that needs to be resolved in order to guarantee the long-term satisfactory functioning of the electricity system. Our model suggests that either the technical coordination has to evolve into a mode of distributed control, or the institutional co-ordinated needs be centralized again.

3. THE RAILWAY SECTOR BEFORE AND AFTER UNBUNDLING

Historically, the railway sector in Europe is a typical vertically integrated industry. A national public operator owns the tracks, the signals, the railway stations, and of course the locomotives and wagons. Suppliers are few and closely related with the historical public operator. Many countries even have their own suppliers. In federalist countries – e.g., Germany, Switzerland, Austria – there are also regional public monopolies, which however generally are integrated within the national railways system (e.g., harmonization of the timetable). The system is strongly determined by national policies and there is often little interconnection between the different national public monopolies. Also, there is little; technical innovation making the sector not very dynamic. In addition, in all European countries, rail is heavily subsidized. Figure 5 summarizes the structure of the railway sector before and after liberalization.

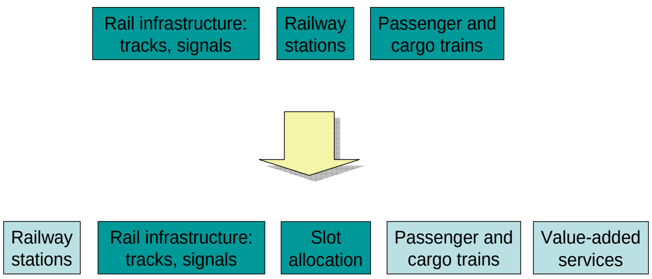

Figure 5: Structure of the railway sector before and after liberalization

Unbundling, in the railways sector, initially takes the form of a separation between infrastructures (tracks and signals) on the one hand and transport (i.e., passenger and cargo trains using these very infrastructures). However it rapidly appears that unbundling is not as simple.

- Indeed, as, in a first step, cargo transport services become commercial (in the European Union as of 2008), appears the necessity to allocate slots in a neutral manner. It thus becomes necessary to create a slot allocator which is independent both of the infrastructure owner and of the train operating companies (TOCs), at least as long as the infrastructure operator and one of the TOCs is still publicly owned. The institutional structure here is very similar to the air transport sector, where an air traffic control (ATC) operator allocates the routes. In principle, the slot allocator can be a commercially oriented company, which however has to be regulated. This question of slot allocation is nevertheless substantially complexified by the fact that there exist at least four different public policy objectives in rail transport, namely cargo, international passenger transport, national passenger transport, and regional/agglomeration transport.

- In addition, as passenger transport becomes liberalized (in the European Union planned for 2010-12) arises the question of the railway stations. They also have to become independent of the TOCs so as not to favor any of the TOCs over another. Again, railway stations can become commercially oriented companies.

From a purely technical point of view, the rail transport system needs to operate as an integrated system. The main challenge here in terms of system integration pertains to the (passenger) timetable, where the allocation of slots is being harmonized. Currently, there exists only one coherent timetable per country, but with the liberalization of the passenger transport it becomes conceivable to have parallel or even competing timetables, thus posing serious problems to the technical integrity of the railway system.

3.1 Characterization of the system relevant functions

The four system relevant technical functions – i.e., interoperability, interconnection, capacity management, and system management – also apply in the railway sector. In this section, we will briefly describe these four functions. To recall, historically all four functions were integrated in the public monopoly.

- *Interoperability* pertains first of all to the usage of the infrastructures: indeed, locomotives and wagons have to be interoperable with the railway infrastructure, i.e., in particular with the tracks, but also with all the safety relevant infrastructures (e.g., signals). At the most basic level, such interoperability pertains to track width, but also to technical harmonization regarding the communication between the TOC and the infrastructure.
- *Interconnection* historically pertained to the different national integrated railway companies connecting to one another. In the federalist countries, it also pertained to the different regional companies connecting to the national monopoly operator. In a liberalized environment, interconnection, in addition to the above, will also pertain to the different TOCs connecting to one another (if relevant), for example when wagons of a certain TOCs are connected to a locomotive of another TOC.
- *Capacity management*, as said above, is historically integrated in the public monopoly operator. In a liberalized environment, however, capacity management takes the form of slot allocation. Institutionally, such slot allocation needs to be separated from the TOCs using the infrastructure. If one of the TOCs and the infrastructure operator remain publicly owned the slot allocator also needs to be independent of the infrastructure operator. Slot allocation in the railway sector is – just like in the air transport sector – primarily a safety matter. The slot allocator thus needs to attribute the available capacity in a way that it is optimally used, yet does not pose any safety threat.
- *System management* historically takes the form of stable timetables. These timetables were produced by the historical monopolistic public operator. In a liberalized environment however, timetables of the different TOCs need to be consolidated and harmonized. Such consolidation and

harmonization in turn should be done by yet another independent body, which ideally is not identical to the slot allocator. Rather, the slot allocator accepts the timetables as constraints and as a limitation for the available slots.

3.2 Determination of the degree of coherence between technical and institutional coordination

At the time when there was one national public railway operator coherence between technical and institutional coordination was ensured by this very operator, and took the form of hierarchy. As a matter of fact, the historical operator determined its timetable which was harmonized with the available slots and interoperability was not a problem. Interconnection between the historical national monopoly operator and the regional operators was also hierarchically organized, whereas international interconnection was firstly less important and secondly handled on a professional level by means of network coordination.

Liberalization is likely to introduce – and already introduces to a certain extent – a certain incoherence between technical coordination and institutional coordination. Indeed while from a technical point of view interoperability, capacity management, and system management will have to continue to be coordinated in a hierarchical manner, there is a certain pressure to allocate slots commercially and even to have competition among timetables. Also, in matters of interoperability a certain competition will arise, which is likely to be arbitrated by suppliers who will be able to take advantage of competing standards (between infrastructure operators and TOCs) by imposing their own standards. In other words, coordination problems are likely to significantly increase as a result of liberalization, which in turn will increase the incoherence between technical and institutional coordination. The question therefore is what implications this decline of coherence will have on performance.

3.3 Consequences on performance

Overall, it is still to early to make an assessment of the performance of the railway sector after liberalization, as liberalization is still little advanced in Europe, except in the cargo segment of the market. However, it is nevertheless possible to make some predictions regarding economic, social, and technical performance.

- In *economic performance* terms, there are likely to be efficiency gains once TOCs compete against one another. The question however is whether these efficiency gains are not simply being compensated by some efficiency losses in the still monopolistic segments of the market. Thus, if cargo is being liberalized, it is likely that the reduced prices will be compensated by increases in passenger traffic. As a matter of fact, it will only be possible to judge the efficiency of the TOCs once all passenger traffic is being liberalized. Also, one would have to judge whether the efficiency of the railway system as such is increased as a result of liberalization. Indeed, such overall system efficiency might be problematic because of the fragmentation of the railway system as a result of liberalization, which will significantly increase transaction costs (e.g., regulatory costs).
- In *social performance* terms, the main challenge will pertain to regional transport. Currently such transport – along with the railway infrastructure – is heavily subsidized, and is not sure that the liberalization will make such subsidies less likely. Rather, what one will have to watch out for is whether the efficiency gains or costs savings in the competitive segments of the market (cargo,

international and national passenger transport) will not come at the expense of an increase in subsidies for regional and agglomeration transport. Again, this might happen because of increased transaction costs, but also as a result of coordination problems, given the fragmented railway system.

- In *technical performance* terms, the main issue is safety. Indeed, the fragmentation of the railways system, and notably interoperability interfaces and capacity management issues, may well lead to safety problems. Furthermore, the multiplication of actors is likely to lead to a multiplication of technical standards, thus increasing problems of interoperability, interconnection, and ultimately safety.

4. INSTITUTIONAL DYNAMICS IN BOTH SECTORS

In the previous two chapters, we have examined the question of coherence between institutions and technology from a static point of view, thus looking in particular at the multiplication of actors and the fragmentation of the (electricity and railway) system. In this chapter, we will examine more closely the institutional *dynamics* resulting from liberalization in both the electricity and the railway sectors. This is based on the assumption – grounded in organizational behavior and institutional theory – that liberalization in general and unbundling in particular is before all an institutional change, which in turn will create new incentive structures for the involved actors, thus triggering a certain dynamics within and among the involved actors. This chapter is structured as follows: in a first section, we will present the theory which will allows us to analyze, in sections two and three, the institutional dynamics of the electricity and the railway sectors.

4.1 Theoretical considerations

As seen above, liberalization in general and unbundling in particular mean, before all, a multiplication of actors. To recall, actors can be individuals, groups, and organizations, which in turn can be public, private, and even third sector entities. Each actor pursues one, but generally multiple goals, which can be conflicting. Organizational behavior theory predicts that each actor, in parallel to achieving its goal(s), also seeks to increase its "discretionary power". (Discretionary) power can be defined as the capacity to get others to do what oneself does not want to do. This means that each actor always also seeks to acquire a certain *capacity to define* its own goals (and this in parallel and in addition to trying to achieve its own goal(s)).

Generally, the goals for any given organization are set by rules which are located outside of these very actors, generally by governance structures. These rules set incentives, which affect both the organization as such, but also the actors inside the organization. In some cases, these rules set commercial incentives (e.g., profit), but in other cases these rules set incentives that pertain to recognition, power, and others more. As said above, all actors strategize to increase their discretionary power. They do so by trying to influence the rules by which they are governed, i.e., by trying to influence the rules in a way that their discretionary power is increased. In other words, actors strategize (1) vis-à-vis other actors and (2) vis-à-vis the rules that govern them so as to (a) achieve their goals and (b) to increase their discretionary power.

Such actor behavior determines the dynamics of any given (actor) system, and it takes place regardless of the governance structure (e.g., hierarchy, markets, networks), regardless of the industry or sector, and regardless of cultural differences. In other words, such actor behavior takes place both before and after unbundling of the network industries. Before unbundling the monopolist basically only had the political authorities to deal with. In organizational and institutional terms, the political authorities were both actors (minister in charge of the monopoly, government, and parliament) whose goals had to be satisfied, and definers of (institutional) rules, under which the monopoly had to play. In other words, goal achievement and incentives were somewhat aligned, even though goals were multiple and changing over time. After unbundling, i.e., in a more liberalized environment, things became more complicated: on the one hand, there is a multiplication of actors, each of which pursues different goals (e.g., profit, control). On the other hand, the institutional rules (i.e., the incentive structures) multiply and also diversify. As a matter of fact, it is now perfectly possible that goal achievement and incentive structures are no longer aligned, and actually even contradictory. It is also possible that any given actor operates under different incompatible incentive structures. This can lead to goal displacement, goal multiplication, and thus to inefficiency. But, such a "confusing" environment can also lead to the fact that the actor can substantially increase its discretionary power, particularly under weak governance. Innovation in general and technological innovation in particular are both means for goal achievement and for increasing any given actor's discretionary power.

In the next two sections we now want examine how such actor dynamics plays out in both the electricity and the railway sector. This will give us an indication whether, to what extent, and how, over time, the above highlighted emerging incoherences between technology and institutions in the electricity and the railway sectors will either be exacerbated or actually reduced.

4.2 Institutional dynamics in electricity

Liberalized electricity markets can develop as three different institutional structures or market designs (Hunt & Shuttleworth 1996): the single buyer model, wholesale competition, retail competition. In this paper we only focus on the latter case of retail competition, which we consider this as the most extreme case of restructuring from an institutional perspective. In this case, the value chain is completely unbundled into different and distinct economic activities. Besides, the commercial activities are often privatized, whereas the regulated network activities are either public or private. The most significant actors and their respective goals are shortly characterized in the following paragraphs. We will specifically focus on the question to what degree the different actors take into account the four fundamental functions that need to be fulfilled in order to safeguard the technical integrity of the system.

- The *electricity producers* operate as profit maximizing firms. They need to cope with the financial risks of their long-term investments in the generation plants. Investments are only attractive if there is sufficient confidence in the market's demand and hence long-term profitability. Before liberalization, vertically integrated firms were allowed to sell electricity to the final customer, based on a cost-plus tariff. Under this regime, investment risks were allocated to the final customers. In a liberalized market however, the producers have to share a considerable part of these investment risks. As a consequence, they will be more reluctant to invest in new power plants, and they will economize on present and future production assets. This causes problems with respect to capacity management, especially security of supply (i.e. generation adequacy). On a very short term strategic behavior of electricity generators might even be contrary to the system needs. In times of acute shortages of electricity supply (like in the California energy crises) producers can maximize their profits by withholding capacity. This does certainly not serve the systems objectives.

- *Electricity traders (wholesale and retail)* can be either completely independent intermediaries, or vertically integrated with the producers. In the latter case they can aggregate demand, possibly by long-term contracts, and thus help to mitigate the investment risks of the electricity producers. This seems to be a quite dominant firm strategy. Under these circumstances it is likely that the traders follow the objectives of the producers. The position of independent traders is characterized by profit maximizing behavior. They are likely to lobby for low network tariffs, and non-discriminatory access to the grid. There is no 'natural' interest in pertaining and financially supporting the fundamental system functions.
- *The network companies (transmission and distribution)* are strongly regulated monopolistic firms that are expected to monitor and sustain the system performance. The unbundled transmission firm is often responsible for transmission and system operations. This means that not only transmission services are supplied, but also critical technical system functions are safeguarded. This includes real-time operational capacity management (like voltage control and disturbance response), and longer term issues like transmission planning. The objectives of these transmission system operators (TSO) are oriented towards the technical functioning of the electricity system and can thus be expected to serve the above-mentioned four fundamental functions. On the other hand, there might also be some profit objectives, especially if these firms are privatized. Since the tariffs of these firms are regulated, they might strategize vis-à-vis the political authorities. Distribution system operators (DSO) only have limited local tasks for the supply of electricity from the high voltage delivery point to the final customers. They need to make sure that there is sufficient and reliable network capacity to satisfy the needs of the clients and the standards approved by government and enforced by the regulator.
- *Metering* is a novel independent activity that was formerly part of the distribution activity. The metering activities are only very seldom organized as distinct economic activities. Mostly this function is vertically integrated either with trader of as part of the distribution company.
- *The regulator* is an independent public entity that monitors and enforces governments' objectives, especially with respect to network access, network tariffs, and the protection of residential customers. The regulator is not able to directly influence the four fundamental system functions. Through the regulatory framework they are able to provide incentives to the DSO's and TSO's in order to serve the technical system integrity.

These short examples illustrate the variety of actors, serving different objectives that are sometimes even contrary to safeguarding of the technical reliability of the electricity system. In this respect, liberalization resulted in diffuse sectorial organization that might not represent a stable institutional equilibrium. The following figure 6 summarizes the likely contribution of the above-mentioned actors to the four fundamental technical functions.

Table 6: Likely contribution of each actor to technical system integrity.

	Interconnection	**Interoperability**	**Capacity management**	**System management**
Electricity producers	-	-	-/+	-/+
Traders	-	-	-/+	-/+
Network companies	++	+	+	++
Metering	-	-	+/-	+
Regulator	-/+	-/+	-/+	-

It appears that the network companies, especially the TSO's, have a very important responsibility with respect to the technical system integrity. However, as a consequence of the vertical unbundling, the opportunities of the TSO's to safeguard these technical functions are limited only to the network. This causes problems, since there are strong complementarities between the network and other components of the system. For example, long-term capacity management requires investments in generation capacity, which has to be realized by the producers.

It seems as if the liberalization policy did not sufficiently take into account the technical consequences of the institutional restructuring. The question is however, whether the technical characteristics can be taken as a given. Firms can be expected to innovate if this serves their objectives. For instance, there is a growing interest in small-scale electricity production. Among others, this mitigates the financial risks for new build power plants. Besides, it also allows serving specific needs of final customers (i.e. product differentiation). There are even considerations to develop so-called smart networks, which enable a stronger technical unbundling of the electricity system that can be compared to the network stricture of the Internet. If this technical development pertains, the institutional restructuring would be followed a technical restructuring of the system. Up to now, we are not able to sufficiently understand and conceptualize the relation between institutional and technological change in infrastructures. Our second case is another illustration for this hypothesis.

4.3 Institutional dynamics in railways

As observed above, in the railway sector liberalization will lead to a multiplication of actors, all of which will pursue their own goals. Let us briefly mention here only the main involved actors with their respective goal(s):

- The *infrastructure operator* will rent out its infrastructure to TOCs at a certain price, which will be regulated. The goal of this infrastructure operator will be to maximize this price and thus revenue by seeking to get the regulator (as price setter). The infrastructure operator will also strategize vis-à-vis the TOCs so as to minimize the costs of using its infrastructure, as well as vis-à-vis the suppliers so as to build train operating material which is optimally compatible with its infrastructure. Finally, it will strategize vis-à-vis the political authorities so as to obtain (a maximum amount of) subsidies for its infrastructure construction and perhaps maintenance.
- The *train operating companies* (TOCs) will pay a few for using the infrastructure. Their profits will stem from the difference between what they charge their customers (chargers and passengers), the

cost of their operations, and the fee for using the infrastructure. The goal of the TOCs will be – in addition to acquiring paying customers – to minimize the infrastructure usage fee, and this will mainly be done by means of lobbying the regulator. While on the "market" the TOCs will be in competition, they will however be united to lobby the regulator when it comes to the access fee and other rules governing their access to the railway infrastructure.

- The *slot allocator* will be, in principle, an independent body both from the infrastructure operator and the TOCs. It will operate under rules set by the political authorities (and to a lesser extent by the regulator), but it will be supervised by the regulator. Its two main goals will be efficiency and safety. Whenever conflicting, the goal of safety will prevail over the goal of efficiency. Besides complying with these two (conflicting) goals, the main strategy of the slot allocator will be to increase its discretionary power vis-à-vis the regulator, the TOCs, and the infrastructure operator. It will do so by trying to set the definitions and rules of what constitutes efficiency and safety in the railway sector.
- The *regulator* will both supervise the slot allocator and set and implement the access rules. Its main goal will be ensure the functioning of the infrastructure, ensuring simultaneously competition, consumer protection (quality, accessibility, affordability), sustainability of the railway system, and safety. These are all conflicting goals, and the strategy of the regulator will be to increase its discretionary power (vis-à-vis the political authorities) so as to be able to set the priorities to its own advantage. Most likely, safety and consumer protection will prevail over competition and (long-term) sustainability of the system.
- The *suppliers* – especially the suppliers of the TOCs (rolling stock) and to a lesser extent the suppliers of the infrastructure operator (e.g., signals, tracks) will substantially increase their power in the liberalized railway sector, especially if they are able to join hands. Their goal of course will be to maximize profits and they will try to do so by standardizing their products. They will thus not only strategize vis-à-vis the infrastructure operators and the TOCs, but also vis-à-vis the slot allocator and especially vis-à-vis the regulator so as to set rules that are favorable to them.

Looking at the above actor dynamics triggered by liberalization in the railway sector, the consequences can hardly be said to be beneficial: each actor strategizes vis-à-vis one or several other actors so as to achieve their goals (e.g., profit, safety) and to increase their discretionary power in the process. This is most likely to increase transactions among all involved actors, and thus transaction and coordination costs. In other words, the multiplication of the involved actors, each having their own goals to achieve and having their own strategy, is ultimately detrimental to the overall railway system.

However, within the broader conceptual framework of the co-evolution between technology and institutions, such actor dynamics is problematic only as long as technology is considered to be a constant. Indeed, when seeking to satisfy the set goals and when seeking to increase one's discretionary power, organizations will always also seek to innovate, be it by way of technology or by way of social innovations. It is therefore perfectly possible that new (technological) solutions to the above coordination problems will be emerging along such actor dynamics. In order to assess whether and to what extent such actor dynamics will ultimately be beneficial or detrimental to the railway system, one will have to examine in more detail what the different actors are likely to contribute to the technical functioning of the railway system in terms of interconnection, interoperability, capacity management, and system management, all problems which had emerged as a result of liberalization.

The following table will thus try to assess for each of the above identified actor whether he is likely to contribute to each of these four functions.

Table 7: Likely contribution of each actor to technological coherence.

	Interconnection	**Interoperability**	**Capacity management**	**System management**
Infrastructure operator	+/-	+	-	-
TOCs	++	-	+	+/-
Slot allocator	-	+/-	++	-
Regulator	-	++	+	++
Suppliers	++	+/-	+	++

Besides indicating which technical problems are most likely in a liberalized railway environment, the above table also indicates possible alliances among actors so as to address these problems. Finally, an overall and more systematic assessment of this table will highlight the potential for (technical) innovation in the above for areas which all are necessary of an infrastructure system to properly function.

CONCLUSION OF THE PAPER

This paper addresses the question of the coherence in the infrastructures. More precisely, it examines the articulation between technical and institutional coherence. It assumes that a certain degree of such coherence is necessary for infrastructures (network industries) not only to properly function, but moreover to be both economically and socially performing. The paper takes the current unbundling of the electricity and the railways sectors as cases so as to analyze whether and how the dynamics of deregulation (liberalization) leads to such incoherence.

Four basic technical functions are identified that need to be safeguarded in order to guarantee the technical integrity of infrastructure systems (i.e. capacity management, system management, interoperability and interconnection). In unbundled infrastructures these functions are associated to different actors with diffuse objectives. The illustrative case studies for electricity and rail transport demonstrate an even growing incoherence between institutions and technologies. The restructuring of these infrastructures have therefore resulted in an unstable situation with unsatisfactory guarantees for the technical system stability. The unbundling of the value chains in electricity and rail transport has resulted in very complex market structures with problematic structures of property rights and decision rights. This situation asks for a more detailed analysis of the technological and institutional dynamics of these sectors. The paper is therefore primarily conceptual in nature, as it seeks to frame these dynamics of the liberalizing network industries in terms of a co-evolution between technology and institutions.

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