Discussion paper series

on the

coherence between institutions and technologies in infrastructures

WP1002
Governing the dynamics of the network industries

Matthias Finger

Ecole Polytechnique Fédérale de Lausanne

Nicolas Crettenand

Ecole Polytechnique Fédérale de Lausanne

Marc Laperrouza

Ecole Polytechnique Fédérale de Lausanne

Rolf Künneke

Delft University of Technology

Edited by

Matthias Finger

Management of Network Industries

Ecole Polytechnique Fédérale de Lausanne, Switzerland

Rolf Künneke

Economics of Infrastructures

Delft University of Technology, The Netherlands

Managed by

Marc Laperrouza

Management of Network Industries

Ecole Polytechnique Fédérale de Lausanne, Switzerland

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

TU Delft — Delft University of Technology

Recent working papers

2010

WP10-01 : The missing link between coherence and performance in network industries – Christof Duthaler and Matthias Finger

WP10-02 : Governing the dynamics of the network industries – Matthias Finger, Nicolas Crettenand, Christof Duthaler and Marc Laperrouza

2009

WP09-01 : Exploring socio-technical governance regimes in liberalizing network industries – Matthias Finger and Rolf Künneke

WP09-02 : ICANN's GAC and the global governance of the Internet: The role of the EU in bringing "government" back to Internet governance – Jamal Shahin and Matthias Finger

WP09-03 : The role of coherence in the coevolution between institutions and technologies – Daniel Scholten

WP09-04 : Matching institutions to technologies: the case of transition to hydrogen in the Netherlands - Daniel Scholten

WP09-05 : Regulating Europe's single railway market: integrating performance and governance – Marc Laperrouza and Matthias Finger

WP09-06 : Policy relevance of new institutional economics – Eva Lieberherr

2008

WP08-01 : Exploring Policy Entrepreneurship – Marianne van der Steen and John Groenewegen

WP08-02 : Does liberalization increase systemic risk in the railway sector? – Marc Laperrouza

WP08-03 : Financial Transmission Rights in Europe’s Electricity Market – Christof Duthaler

ECPR – Standing Group on Regulatory Governance in Network Industries
As part of ECPR's Standing Group on Regulatory Governance Biennal Conference
Dublin, June 17-19 2010

*** please do not quote without the permission of the author ***

Governing the dynamics of the network industries[1]

Matthias Finger, EPFL (lead author)
Nicolas Crettenand, EPFL
Marc Laperrouza, EPFL
Rolf Künneke, TU Delft

Abstract

This paper wants to further develop the theory of co-evolution between technology and institutions in the network industries by addressing one of the critiques that is generally raised, namely the lack of taking into account its dynamics. The paper outlines the main steps in the conceptualization of the evolving network industries in the context of liberalization and concludes with considerations about how to govern their dynamics.

Introduction

It is generally accepted that the network industries have evolved over the past 20 years and become more liberalized. In parallel, the technologies in the different network industries have also somewhat evolved, especially the ICTs that are underlying all other technologies. It is also agreed that the governance of some of these network industries has evolved from traditional state-owned enterprises to unbundled enterprises under regulation to new, more self-organized and decentralized forms of governance. But, not only is the latter form of governance still under discussion, moreover, it is not yet established in the literature whether this is an almost "automatic" evolution or whether these three forms of governance represent different more or less stable/coherent configurations.

This is basically a theoretical/conceptual paper. It is grounded in the framework of co-evolution/coherence between technology and institutions in the network industries (Finger, Groenewegen & Künneke, 2005; Finger & Varone, 2006; Künneke & Finger, 2007). However, in this paper, I want to push the theoretical developments a bit further, and ask the question what the dynamics of the network industries actually is and how it can or should be governed. By doing so, I will address one of the three critiques that are generally formulated against the framework of coherence and co-

[1] I would like to thank Nicolas Crettenand and Marc Laperrouza for their comments having helped me to improve this paper.

evolution of the network industries, namely the critique pertaining to its lack of dynamics. Indeed, if there is an evolution from monopolistic, via regulated to decentrally governed infrastructures, the question arises as to whether this process – characterized by both technological (distributed, inverse) and institutional changes (regulation by ownership, sector-specific regulation, competition and/or self-regulation) – unfolds organically or whether it can or should be facilitated by appropriate policies on the governance of evolving infrastructures.

This paper is thus structured as follows:

1. In a first section, I will present the basic elements of the framework of co-evolution and coherence between technology and institutions. More precisely, I will schematically present the three main stages or models of the evolving infrastructures, namely the original traditional stage/model of integrated public ownership or delegated management (still prevalent in the water and sometimes the railway sectors), the stage/model of unbundled, partly privatized sectors regulated by sector-specific independent regulatory authorities) prevalent in the cases of electricity, gas, air transport, and sometimes railways), and the emerging model of decentralized competing and weakly regulated network industries as in the cases of telecommunications and postal services. I will also present the main three critiques that are generally addressed to this theory.

2. In a second section, I will relate these three models/stages to different theories, namely public management in the case of stage/model 1, regulatory economics in the case of stage/model 2, and common-property resources and self-regulation theories in the case of model/stage 3.

3. In section three, we will then discuss the dynamics at both the technological and the institutional levels, both of which, combined, have led to these models/stages. In particular, we will critically discuss whether these are stages or simply different models, and what the underlying forces of such change are. I will also highlight the particular role played by the different types of actors.

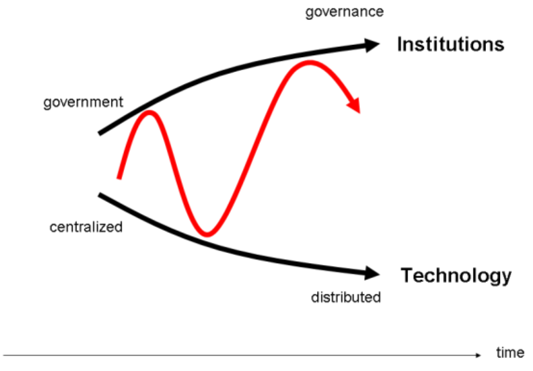
4. In the concluding section, we will focus on the governance of the dynamics, i.e., the governance of the co-evolution between technology and institutions in infrastructures so as to improve the performance of the infrastructures in all its dimensions.

<u>Initial conceptual framework</u>

This is primarily a conceptual paper. It is grounded in the theory of co-evolution between technology and institutions as initially laid out by Finger, Groenewegen & Künneke (2005) and subsequently further developed by Künneke & Finger (2007). In this first section, I will present this theory in five steps. I will conclude the section with a critical appraisal of this theory.

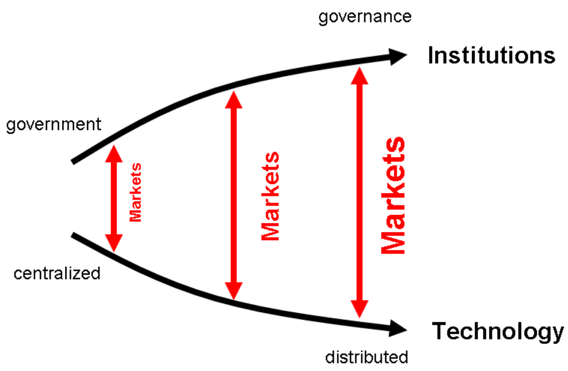
Co-evolution

In a first step, the framework postulates that infrastructures – or rather infrastructure systems – co-evolve as a result of an interplay between technology on the one hand and institutions on the other. The evolution of technology can be characterized as going, over time, from centralized technologies to more distributed technologies. Similarly, in terms of institutions, the evolution goes from centralized institutions (government) to more "decentralized" institutions governance, involving multiple actors at multiple political levels. These two evolutions mutually influence each other. Graphically, the foundations of the basic model can be presented as follows:



Markets

In a second step, the framework postulates that this (co-)evolution is related to the development of markets, as the emergence/creation of markets constitutes the very purpose of liberalization: more concretely, as technologies evolve from centralized to de-centralized technologies and institutions evolve from government to governance, the size/value of the market increases, market opportunities open up, the logic of the market (as opposed to the logic of government) expands, and, in principle, more market actors emerge. According to this framework, markets in the infrastructures are basically constrained between the state of technology at any given time and the institutional conditions at any given time. In other words, markets in infrastructures are bounded both by technology and institutions, yet nevertheless continue to grow.[2] Figure No.2 summarizes this second element or step:

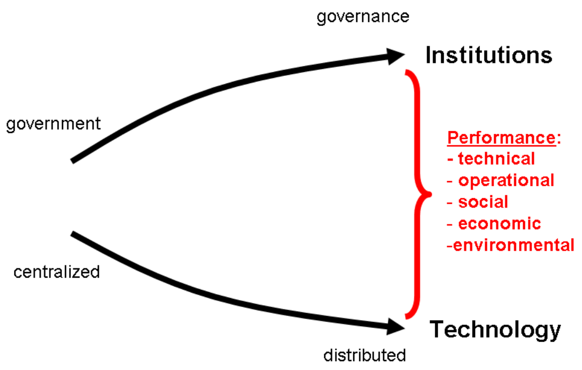


[2] For a critical view on this automatic emergence of markets, see below the discussion on dynamics.

Performance

As a next step, we relate co-evolution between technology and institutions to performance. The liberalization of infrastructures perspective of course only saw economic performance as the relevant performance criteria, and among economic performance basically only allocative efficiency was considered to be relevant. This is however a far too narrow way of looking at performance. Even from an economic point of perspective, one may want to take a more long-term view, valuing also dynamic efficiency, and by doing so taking into account innovation and investments. Furthermore, in the network industries and besides economic performance criteria other criteria are generally equally important, namely operational criteria (accidents, incidents, punctuality), social criteria (equity, universal service provision, etc.), environmental criteria (e.g., sustainability), and technical criteria (e.g., resilience, robustness).

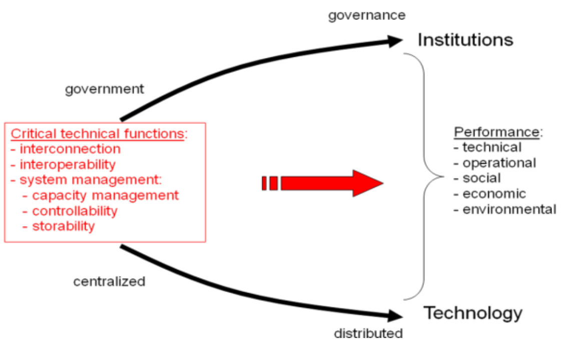
It is important to note that economic performance objectives are only one among several other objectives, and furthermore that there is a trade-off among these objectives. One cannot optimize all these objectives at the same time. Also, which objectives are more important than others is a matter of political choice, and this political choice, in turn, is determined by the power relationships of the actors involved (see section on dynamics below). Figure 3 summarizes this third step of the theory:



Critical technical functions

In a fourth step, the theory introduces the idea that, in the case of infrastructure systems, there are a series of critical technical functions that need to be ensured so that these systems are performing (reference to our article). The identification of these critical technical functions has somewhat evolved over time. At the present moment, I think that the following three critical technical functions need to be ensured for infrastructure systems to function, namely (1) interconnection, (2) interoperability, and (3) system management. System management in turn must be subdivided into the three following critical technical sub-functions, namely (3a) capacity management (i.e., the management of the limited capacities in all infrastructures), (3b) controllability (i.e., the ability to control the overall system as a system), and (3c) storability (i.e., the ability to buffer the system somewhat).

These three critical technical functions are key because they will influence the performance of the overall system in its five above defined functions. Figure No.4 summarizes this fourth stage of theory development:



Configurations

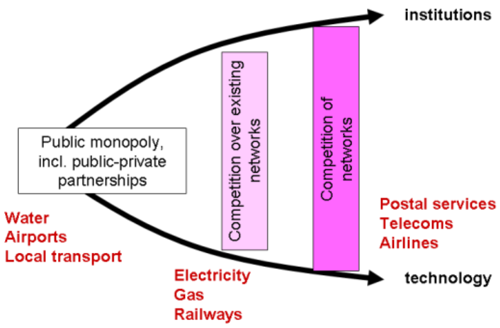
As a fifth step, the framework postulates a certain configurations, within which a certain coherence between technology and institutions exists. At the current stage, three configurations are identified, which, in themselves are said to be coherent, namely:

- The traditional public monopoly, whereby a given infrastructure is owned by the state and managed either by a public administration or a public enterprise; this stage characterizes the infrastructures before liberalization. However, there is also a certain variation of this configuration, namely when the infrastructures are owned by the public authorities, yet managed by private operators in so-called public-private partnerships (PPPs). Typical water (distribution and sewerage), airports, and local/regional public transport are such configurations.

- The liberalized, i.e., unbundled infrastructure, whereby service providers are competing on the basis of a monopolistic infrastructure (network); governance at this stage is ensured by way of independent regulatory authorities; this stage characterizes the current configuration of liberalized infrastructures in electricity, gas, and railways.

- A next or future stage, whereby infrastructures become much more fragmented and decentralized, characterized by the competition of loosely coupled networks. This configuration currently characterizes the telecommunications infrastructures, as well as the postal services and the airlines. Possibly, electricity is moving from the previous to this configuration.

These are three configurations of a certain coherence between technology and institutions. Figure No.5 summarizes the 5th step of the framework:



In the past, a series of criticisms have been addressed to this framework. I will only refer to these criticisms which are actually constructive and aim at improving the theory. In particular, the following three substantial criticisms have been made:

- It is said that coherence between technology and institutions is ill defined: there are no concrete criteria of what coherence actually is and how it can be measured? In the framework, coherence is strongly related to the critical technical functions, but it is not exactly clear how.

- Secondly, it is said that the relationship between coherence and performance is ill defined: how exactly does coherence relate to performance?

- Finally, it is said the theory lacks a proper conceptualization of the dynamics: what is actually driving the dynamics? How does the dynamics relate to the coherence (e.g., innovation; how much coherence or incoherence is optimal to drive the dynamics)? And is such dynamics unidirectional only?

In this paper, I will address the third criticism only. The two other criticisms are currently being addressed by another paper we are working on.

Theoretical foundations

The purpose of this paper is thus to conceptualize the dynamics of the infrastructures so as to be able to design a possible governance of such dynamics. As a first step in this direction, I will identify the theories that characterize each of the above identified configurations. The purpose of doing so is to explore to what extent these configurations are actually stable and, if they are not, how these configurations would evolve.

The first configuration – i.e., the public monopoly and its evolution, the public-private partnership – is being covered by a series of theories, the most important of which being public management (public administration) and its various evolutions into new public management and public contract theory. Traditional public administration theory has indeed evolved, but not in the direction of more competition. Rather, it has evolved into the direction of giving the public entities more autonomy in their management. Furthermore, public-private partnerships have not really evolved out of new public management either. The theories underpinning PPP activities rather stem from institutional economics and principal-agent theory evolving into contract theory.

New public management and contract theory are quite static in that they consider that the relationship between the public authorities and the autonomized agency or the private partner can be designed in a way that this relationship can be perpetuated. Furthermore, both do not consider outside forces to bring any change to this configuration. The only conceivable change could be privatization which however would not fundamentally change anything, as it would simply require an adaptation of the contractual relationship.

The second configuration – i.e., the unbundled infrastructure system – is basically covered by regulatory economics. Regulatory economics is the idea to create and sustain markets in sectors/industries where certain segments remain monopolistic while others can be competitive. Regulatory economics thus deals with problems of designing institutions (rules) that create and sustain such markets. Such rules pertain to accessing the monopolistic infrastructures, especially to the cost of accessing such infrastructures, to using scarce infrastructure resources, especially to the pricing of such scarce infrastructure resources, as well as to managing the systemic functions, especially to pricing these functions and allocating them to the different users. Regulatory economics furthermore also pertains to questions of investment and long-term sustainability of the monopolistic infrastructures. The focus of regulatory economics is exclusively on markets: creating and sustaining markets in infrastructures is the paramount objective and all other dimensions which are also being regulated – e.g., technical aspects (safety for example) and political considerations (universal service or public service) must be subordinated to this market imperative so as not to distort these infrastructure markets. Regulatory economics is neo-liberal in nature in that regulation should only take place as a last resort, i.e., if there are stable monopolistic bottlenecks and if regulatory costs are lower than the inefficiencies incurred by the absence of regulation. Regulatory economics does not per se exclude dynamics: it does indeed consider that monopolistic bottlenecks may disappear as a result of technological evolution, even though it says nothing about how such technological evolution occurs and simply assumes that technological progress automatically leads to improving markets. Potentially, then, the unbundled regulated infrastructure could evolve into free markets where monopolistic bottlenecks no longer exist and where therefore regulation (access to the monopolistic bottleneck, usage of the scarce resources associated with the bottleneck, systemic regulation) no longer is needed. Unfortunately, this theoretical consideration – or rather wishful neo-liberal thinking – does not really occur: this is basically because even economic regulation develops an institutional dynamics of its own which does precisely not make it superfluous. Rather the opposite is the case, once such regulation has taken hold, it will generate more regulation to the point that the evolution from regulated infrastructure systems to markets becomes almost impossible, even though it would be technologically conceivable.

There does not currently exist a theory for the third stage I have called competing networks. Neo-liberal theory would simply see this third stage as being the stage of functioning markets. In this third stage, competition regulation would prevail and no other regulation would be needed any longer. It is true that from a regulatory economics point of view there only exist full-fledged markets once monopolistic bottlenecks have been removed. Thus, neither market economics nor regulatory economics can really deal with the phenomenon of competing networks. Such networks, however, are a reality. While there are no longer any bottlenecks one needs to regulate access to, competing networks continue to need regulation, namely regulation of interconnection and of interoperability, but sometimes also regulation of scarce resources (e.g., spectrum). In short, we do not really have a theory of how to regulate or govern such competing networks, other than piecemeal approaches to some remaining bottlenecks.

Some people have tried to get at these scarce resources by trying to apply common pool resource theory to the network industries (de Bruijne & Kars, 2007). Common pool resources are resources where there exists rivalry but not excludability. However, in the network industries, non-excludability (e.g., to spectrum or to airspace) does hardly exist and I do not think that common pool resource theory can be applied here. No other theory that could apply in the case of competing networks really comes to mind.

In short, for stages one and two theories exist which are static in nature. For the third stage/configuration, no real theory exists. None of the theories helps us to discuss the evolution from one of the stages/configurations to the other. We thus need to look at the transformation process from an empirical point of view.

Transformation of the network industries

In this section, I want to look at the dynamics that leads us from stage one via stage two to perhaps stage three. I will do this in three separate steps: in a first step, I will look at this transformation from a general perspective analyzing both the institutional and the technological dynamics. In a second step, I will bring in the actors into this dynamics. Finally, I will discuss whether these are steps driven by an underlying dynamics or stable configurations.

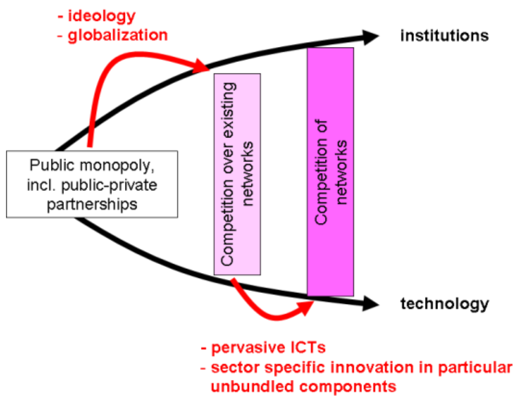
A general look at the evolution of the configurations

The framework considers the evolution of the above configurations as resulting from combined institutional and technological change. As said above, it is however not clear, from the framework, which is too general, how institutional and technological changes interact so as to create this dynamics. However, before being able to analyze this very interaction, it is necessary to first understand the dynamics of both institutions and technology separately:

- Institutions, I have said, have evolved, in the infrastructures, from government controlled monopolies to new forms of governance, leading to both to the multiplication of levels (local, regional/subnational, national, regional/supranational and global) and actors, namely government, business and third sectors as being involved in the governance of the infrastructures (see below regarding actors). The question now is what drives this institutional evolution (besides technological changes). Two particular forces must be mentioned here, namely ideology and globalization. The ideological force is important, as it has significantly contributed to weakening nation-states by pressuring them to privatize, to deregulate and to outsource, thus leading to the creation of new actors that have come to provide the services formerly provided by (monopolistic) government, as well as new actors – regulators – that must ensure that these infrastructure systems continue to perform. The second institutional force is globalization. Globalization indeed leads again to a weakening of the nation-state – in part because globalization creates structural financial problems for nation-states forcing them again to privatize, as well as legitimation problems, forcing them to improve upon their services – and to the creation of new supranational actors in the form of transnational corporations and corresponding business associations, as well as to new, supra-national actors which now have the role to coordinate the increasingly global economy. Such institutional change has been particularly important, I would argue, in the evolution from stage 1 to stage 2, i.e., in the evolution from integrated public monopolies to competition over the networks. Indeed, this change was basically ideologically motivated (with the exception of telecommunications, technology was not ready for such a change), as well as driven to a certain extent by new global firms who saw business opportunities in unbundled infrastructure systems (considering that business is only interested in the lucrative portions of the infrastructures, thus unbundling).

- Technological systems, as said above, have evolved from more integrated one to more distributed and therefore complex ones. This creates additional interfaces because of a multiplication of nodes and links. Examples can be found in all the infrastructures. Let me mention, for example, smart grids which reflect an evolution in grid technology and metering, which allows for much more active grid operations. Other examples are railways, where new interfaces between trains (e.g., ERTMS) and infrastructures allow for better interoperability and thus for more distributed operations, just as was the case earlier in air transport. The question again is what drives such change of technological systems (besides institutional changes, see above). The most obvious force that comes to mind here are the information and communication technologies, which basically lower the transaction costs (coordination costs, monitoring costs) and therefore allow for a certain decoupling of the various systems components and whose coordination is subsequently ensured by the ICTs. In addition, a second technological force is sector specific and pertains to the various systems' components, where independent and sector-specific technological innovation is now taking place. I would argue that the evolution from stage 2 to stage 3, i.e., from the unbundled infrastructures where competition is taking place over existing networks to competing networks altogether is basically driven by such technological changes (see below).

Figure No.6 summarizes these two forces driving institutional and technological change in the various infrastructures:



However, having identified the forces that independently drive the institutional and the technological dynamics in the infrastructures does not yet help us to better understand the interaction (and thus the co-evolution) between technology and institutions. It is nevertheless clear that the institutional change between stages 1 and 2 has triggered technological innovation in the various unbundled system components. This – combined with the pervasive role of the ICTs – as in turn significantly contributed to the evolution from stage 2 to stage 3. But I think that in order to better understand this interaction one has to look at the particular role of actors.

Actors and dynamics

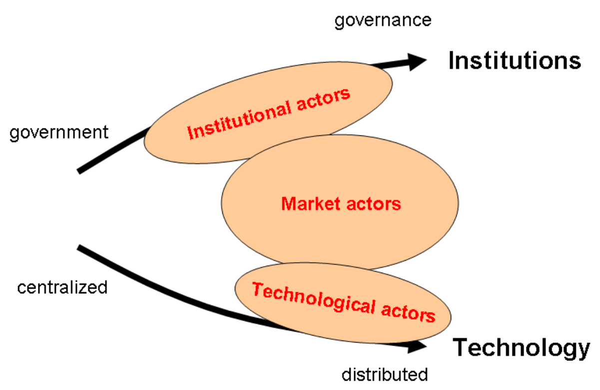
In my opinion, neither the institutional dynamics nor the technological dynamics and even less so the interaction (co-evolution) between these two can be understood without introducing actors. So far, I have not really mentioned actors and pretended that the different forces almost unfold by themselves. This is of course not the case. Let me therefore now distinguish three types of actors and identify the main incentives they respond to. This will then help us better understand the dynamics of the infrastructure systems:

- <u>Institutional actors</u>: these are actors that are capable to define the institutional conditions (i.e., the incentive structures) under which all other actors, including themselves, behave. There are three types of institutional actors, namely political actors, public administrators, and regulators. Political actors are mainly concentrated at the national and the infra-national levels (state and local). Public administrators can be found at the same levels plus also at some supranational and even global levels. Regulators in turn can mainly be found at the national and supranational levels. The relationships between these three types of institutional actors are complex, with the political actors having the ability, at least to a certain extent, to define the basic rules. However, regulators and public administrators – especially at the supra-national levels – also have a considerable potential to define rules. Institutional actors basically respond to incentives that relate to discretionary power and less to reputation or money.

- <u>Technological actors</u>: these actors have the ability to foster technological innovations. By doing so, they force economic and institutional actors to react, to adapt and ultimately to change. There are mainly three types of such technological actors, namely university fundamental and applied research labs, intra-firm applied research labs and autonomous start-ups, many of which may have originated inside universities. There are relatively little relationships among these three types of technological actors, except for that fact they compete and by doing so stimulate one another. Technological actors mainly respond to reputational and to financial incentives and operate of course within particular regulatory boundaries. Technological actors emerge parallel to the creation of markets in the infrastructures, as competition is one of the drivers of technological innovation.

- Market actors: market actors quite logically emerge parallel to the process of creating markets in the infrastructures, i.e., parallel to liberalization and to a lesser extent parallel to privatization. As liberalization progresses, these market actors are increasingly the only ones capable to provide the various infrastructure services (see above regarding performance). There are two types of market actors as well, namely public enterprises, which may have become privatized and thus have become so-called incumbents in their home country, and new entrants, which may come from outside the respective sectors or be former public enterprises entering new markets. In the network industries, markets are relatively concentrated, which means that there is always a quite limited number of market actors in any sector. In general, the market actors respond to financial incentives, which can be either the consumers of the services or the public authorities paying for or subsidizing certain services. Especially in the second configuration, there also exist, besides the market actors, infrastructure operators (e.g., electricity grid operators, railway infrastructure operators, air traffic control service providers, and others more) who are not really market actors as they mostly respond to regulatory signals and incentives.

It is all these actors, combined, which create the dynamics, i.e., the institutional, the technological, and the market dynamics. In other words, no actor – not even the political actors – has the ability to shape these dynamics by itself. Rather, all actors behave strategically vis-à-vis one another and the dynamics is precisely the result of all these strategic behaviors combined. Figure No.7 summarizes the above considerations:



How stable are configurations?

In other words, there is no dynamics in the infrastructures without or outside of the actors. This also means that the very nature of these dynamics as well as its outcomes in terms of performance (see below) is ultimately the result of the dynamics. The question I would like to address at this point, however, is whether – given the above described dynamics as driven by the actors – the three identified configurations are indeed stable.

To recall, and as I have shown above (figure No.5), the need for configurations results from the idea of coherence, more precisely from the idea that the three critical technical functions (interconnection, interoperability, and system management) need to be ensured by way of a certain alignment between a given state of technology and corresponding institutional arrangements. However, for each of the three configurations, different combinations of technology and institutions are possible so as to ensure such coherence. The way by which technology and institutions are combined (aligned) will in turn determine the performance of the infrastructure systems.

The argument made above is that the actors drive the dynamics of the infrastructure systems. This would mean that none of the configurations is stable, as the multiplication of actors, especially the increase in numbers of technology actors will trigger ever more dynamics. However, all actors are incentivized by rules, which in turn are shaped at least by certain actors, namely institutional actors (Crozier & Friedberg, 1977. In this sense, each configuration represents a certain – more or less stable – balance of power among the actors involved, i.e., an institutionalized power relationship. This also means that configurations, even though not optimal from a performance point of view, can nevertheless be relatively stable given the institutionalized power relationships. In this case, what then drives the dynamics, i.e., destabilizes any given institutional relationship.

Such institutionalized power relationships can be destabilized in two ways, by actors or by (perceived problems of) performance. Certain actors – especially institutional actors and technological actors – have the ability to destabilize the institutional relations: institutional actors by way of changing the rules and thus the incentive structures; technological actors by altering the behavior of the market actors and thus by affecting the performance. Performance – especially problems of performance – can destabilize the institutionalized power relationships because it will create pressure on the actors to align themselves with performance objectives: actors which will have to align themselves can be market actors (which have to live up to the performance expectations created by innovators) or institutional actors (which will have to change the rules so as to align them with changed performance expectations. In both cases, configurations will evolve but only to the extent that a certain coherence between technology and institutions is maintained so as not to jeopardize the three critical technical functions. So, what does that all mean for the governance of the dynamics of the infrastructures?

Governing the dynamics of the network industries

In this final section, I will develop a conceptualization of how to think about the governance of the dynamics of the network industries. In order to do that, however, I have to first recall the governance of the three configurations that were identified in figure no.5. As a next step, I will relate the dynamics to performance (see also figure no.3). Finally, I will discuss how the co-evolution between technology and institutions should be governed.

Governing the configurations

In figure no.5, I have identified three configurations – public monopoly, competition over existing networks, and competition of networks – and located the current state of the liberalization of the different infrastructures within these three configurations. I stated that each of these three configurations is characterized by a certain coherence between technology and institutions in that the three critical technical functions are taken care of by particular modes of governance. New Institutional economics distinguishes between three such modes of governance, namely hierarchies, markets and networks, also called hybrids (Williamson, 1996). Table no.1 illustrates how the different critical technical functions are governed in the three configurations:

	Public monopoly	Competition over networks	Competition of networks
Interconnection	Network	Network	Market
Interoperability	Hierarchy	Hierarchy	Network or hierarchy
Capacity management	Hierarchy	Hierarchy	Market
Controllability	Hierarchy	Hierarchy	Market
Storability	Hierarchy	Market	Market

These three configurations are relatively stable. In each of them, the way the critical technical functions are governed is coherent with the state of the current state of technology. Above, I have argued that the dynamics of the network industries, i.e., the evolution from one coherent configuration to another is basically driven by the actors. They will make the different configurations evolve, being aware, however, that subsequent technological change may lead to yet other coherent and stable configurations not listed above. Also, it must be mentioned at this point this evolution can actually go into both directions, i.e., towards more markets, but also towards less markets (see figure no.2), depending on the strategic behavior of the actors.

Dynamics and performance

To recall, each of the three configurations is coherent between the state of the technology and the way the critical technical functions are governed. A certain performance – in all its 5 dimensions, i.e., operational, technical, economic, social and environmental – is associated with each configuration. Different trade-offs between the 5 performance indicators are conceivable even for the same configuration, but further research will have to identify exactly what performance tradeoffs are possible. The dynamics of the network industries – i.e., the dynamics created by the co-evolution between technology and institutions – should, in principle, always lead to better performance, ideally in all its five dimensions. However, the actors involved in providing the infrastructure services will always seek the performance level that suits their interest and that they can get away with given the market and the regulatory constraints. In this sense, it is not necessarily true that the dynamics will automatically lead to better performance in all its five dimensions.

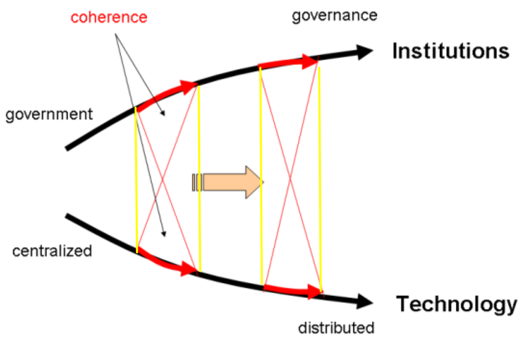
From a normative point of view, it is desirable that the co-evolution between technology and institutions leads to better performance in all the five dimensions. However, since – in the age of governance – none of the actors is located above the other actors, the performance objectives are set by the involved actors themselves, i.e., the actors may well define the performance objectives according to their own strategic interests (e.g., profit, power, recognition), which should in turn confer them a competitive advantage over the other actors. It is thus imperative that the performance indicators are set in a way that they push all involved actors to excel, rather than to become complacent, knowing however that there are limits to performance and that these limits are set by the way the critical technical functions are governed, i.e., the coherence between technology and institutions.

Governing the dynamics

Improving performance will be the combined result of technological and institutional evolution. This is both a push and a pull relationship. It is "pull" because some of the performance indicators cannot be set by the market, because they are either externalities (e.g., environmental and social performance), or because the market is not fully functioning (yet). Where the market is functioning, there may be push factors such as in the case of price, service quality, innovation, i.e., static and to a lesser extent dynamic efficiency.

One of the two dimensions of the governance of the dynamics thus must consist of promoting market based solutions to infrastructure provision wherever possible (see below). This means that the different configurations (where a certain coherence exists between technology and institutions) should evolve to include ever more market-based or network-based modes of governance of the three critical technical functions, rather than hierarchy-based ones. And where a hierarchy mode of governance prevails, static or cost-based regulations should be replaced by dynamic or incentive-based regulations. Similarly, the technological evolution in the areas of the five critical technical functions should be such that market-based modes of governance become viable. Such technological evolution can again be incentivized by appropriate regulations (e.g., incentives for technological innovation).

If this is not the case, i.e., if an incoherence between technology and institutions is introduced in the co-evolution between technology and institutions the performance of the infrastructure systems will suffer. Figure No.8 summarizes this idea in lieu of a conclusion:



Conclusion

This paper is a contribution to the development of the theory on the co-evolution and coherence of technology and institutions in infrastructures. It addresses in particular one of the three criticisms that has been addressed to this framework/theory so far, namely the criticisms pertaining to the lack of conceptualization of the dynamics. In order to better understand and conceptualize such dynamics, the paper introduces the role of actors and subsequently conceptualizes the governance of such dynamics.

References

de Bruijne, M.L.C. & M. Kars (2007). *CPR theory as a guideline for capacity management in infrastructures?* Paper prepared for the 11th International Research Symposium on Public Management, Potsdam

Crozier, M. & E. Friedberg (1977). *L'acteur et le système*. Paris: Seuil.

Finger, M., Groenwegen, J. & R. Künneke (2005). The quest for coherence between institutions and technologies in infrastructures. *Journal of Network Industries*, Vol.6, No.4, pp.227-260.

Finger, M. & F. Varone (2006). Bringing technical systems back in: towards a new European model of regulating the network industries. *Competition and Regulation in Network Industries*, Vol. 1, No.1, pp. 89-108.

Künneke, R. & M. Finger (2007). Technology matters: the cases of the liberalization of electricity and railways. *Competition and Regulation in Network Industries*, Volume 8, No.3, pp.301-333.

Williamson, O. (1996). *The mechanisms of governance*. Oxford: Oxford University Press.