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Innovation Systems: From Classic Models to Those Linked to Economic Development

1.1. NISs: relevant approaches

Broadly disseminated for the past 20 years, the NIS concept has found practical and intellectual consistency in academic circles as well as within political contexts and in international organizations (OECD, European Commission and UNCTAD). This rapid dissemination of the approach was not without consequence. Not only is the literature on the topic abundant, but it is also extremely ambitious in what it seeks to understand and explain. Finally, the interpretations of NIS vary remarkably from one to the other and sentiments can sometimes be quite diverse. With this in mind, the open and flexible nature of NIS is generally accepted and entails the possibility, with regard to the different facts analyzed, of accentuating certain aspects or suggesting different hypotheses without making the concept lose its consistency. Beyond the different approaches adopted, there are, however, recurrent semantics in most of the interpretations. A number of characteristics converge to gain credibility of the approach and the research carried out.

In this regard, we will try to first examine the plural nature of NIS (section 1.1.1) before detecting the common characteristics and the foundations of this approach (section 1.1.2).

1.1.1. *NISs and conceptual flexibility*

Conceptual pluralism, as Edquist [EDQ 97] called it, relates to the spirit of the approach, given the many variations based on this concept. Far from being a stable and unified concept, the diversity and huge scope of the approach are widely considered as actual advantages. Like Lundvall [LUN 02a, p. 221] put it, "The pragmatic and flexible character of the concept may be seen as a great advantage since it makes it useful for practical purposes". Edquist [EDQ 97, p. 27] highlighted the potential justification when he wrote: "In the early breakthrough period of a new technology area it is normal to find different solutions competing. It is important to allow such diversity so that we do not prematurely exclude solutions that may have large potential". Here, the undefined character of the NIS is sought because it is inherent in the conceptual foundation of the NIS and its evolutionary footprint, marked by diversity and variety [MCK 91]. It is in fact through their convergent and divergent tendencies that NIS still makes sense [NIO 92]. By attempting to accept this logic, we arrive at a solution that can shift the question from the conceptual rigor of the NIS to the subject of its analysis: the elements to be taken into account depend on the object studied [EDQ 97]. However, there a number of legibility issues with the approach. These problems are a sign of an evident weakness that research must address in order to ensure that the NIS is not under theorized [LUN 92] or not better suited terminologically [EDQ 97]. Nevertheless, this does not seem to have been taken seriously because, despite the number of attempts at clarification, there are two main conceptualizations of NIS.

According to Lundvall [LUN 92], List was the first to prepare the ground for the conceptual structure of NIS. In his 1841 publication, *Das Nationale System der Politischen Ökonomie*, List showed the importance of knowledge, links between scientific and technological institutions, the production sector and foreign technology required for economic development. It was only in the 1980s that the approach really spread because of the impetus given by three main publications: that of Freeman [FRE 87], *Technology policy and economic performance: lessons from Japan*; that of Lundvall [LUN 92], *National innovation systems: toward a theory of innovation and interactive learning*; and finally, that of Nelson [NEL 93], *National innovation systems: a comparative analysis.*

As in the evolutionary tradition of Nelson and Winter [NEL 82], the first works undertaken criticized the hypotheses put forward by the neoclassical theory of the firm. These hypotheses included the idea that firms, equipped with a perfect rationale, knew the best available technology. The initial studies adopted in line with the innovation economy attempted to thus build on the determining factors of the innovation process and divide the stages of a linear mode. However, this was soon replaced by the interactive model of innovation [KLI 86] that made it possible to go beyond the linear input/output vision and represent the different types of innovation as a continuum, going from incremental innovations to radical innovations.

In this regard, the different phases of innovation are interlinked by the feedback effects between the different stages of innovation activities. From there, innovation does not end once the diffusion/imitation phase ends. On the contrary, innovative actions are influenced by interactions between the different actors: researchers, marketing experts, consumers, etc.

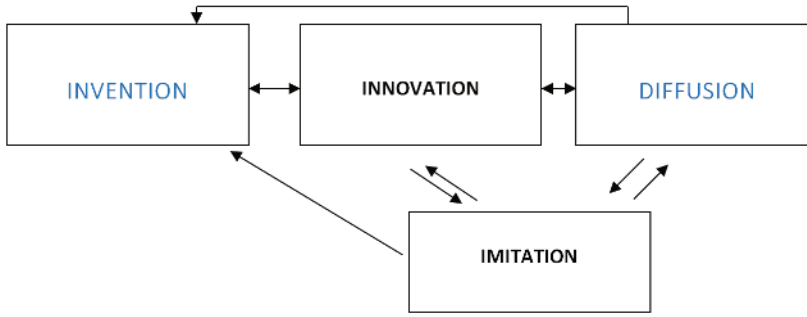

Figure 1.1. *Interactive model of innovation (source: [CAN 00])*

The year in which the term "NIS" was first used in writing is not clearly known and neither is the person who used it. Archibugi and Michie [ARC 97] attribute the essence of the term NIS to Freeman [FRE 87], who in turn attributes it to Lundvall [FRE 95]. According to Edquist [EDQ 97], it is Lundvall who coined the title *National systems of innovation* in the fifth part of *Technical change and economic theory* [DOS 88], which consolidates the contributions of Nelson, Freeman and Lundvall. But according to a recent statement by Lundvall [LUN 02a], it is Freeman [FRE 82] who, in an unpublished document for the OECD, used the NIS concept for the first time. One of the main aspects of his article titled "Technological infrastructure and international competitiveness" tries to explain why and how the world economical supremacy shifts in parallel with the presence of national institutional models.

However, while the concept originated from Freeman [FRE 82], the real pioneers of the NIS approach are Freeman, Lundvall and Nelson, who presented their preliminary ideas on the subject in the work by Dosi *et al.* [DOS 88]. This publication had a huge impact on the development of systemic approaches to innovation. Without claiming to be exhaustive, other researchers have significantly contributed to making the desired approach

richer [PAT 94, NIO 92, EDQ 97, MUC 03, ARO 15]. At this level, as shown in Table 1.1, the accepted definitions differ in nature, while building a common platform, the main features of which are elaborated on in section 1.1.2.

Author	Definition
Freeman [FRE 87]	A network of institutions in the public and private sector, whose activities and interactions introduce, import, modify and diffuse new technologies
Nelson [NEL 93]	An institutional environment whose interactions determine the innovative performance of national firms
Lundvall [LUN 92]	Elements and relationships that interoperate within the production, diffusion and use of new knowledge
Patel and Pavitt [PAT 94]	National institutions, their challenging structures and their competencies that determine the speed and direction of technological learning in a country
Metcalfe [MET 95]	The institutional framework that contributes separately or collectively to the development and diffusion of new technologies, and provides a structure within which governments shape and improve policies that influence innovation processes
Niosi *et al.* [NIO 93]	An interconnected system of public and private firms, universities and government agencies aiming towards scientific and technological production within national borders
Edquist and Lundvall [EDQ 93]	The national innovation system composed of institutions and economic structures that influence the speed and direction of technological change in the society

Table 1.1. *Definitions given to NIS (Source: [NIO 02])*

In order to better understand the NIS approach and make it clearer, several taxonomies were developed [GAR 95, SPE 00]. While this classification is especially simplistic, it defines the basis for a common interpretation.

In this respect, three distinct perspectives are generally associated with the NIS model: Lundvall's theoretical contribution and building of the concept (1992), Freeman's historical perspective (1987) and Nelson's empirical description (1993). The representation of the three main approaches can be summarized in Table 1.2 (R&D: research and development).

Author	Context studied	Unit of analysis	Analytical structure
Freeman [FRE 87]	Japan	Socioeconomic adaptation	MITI's role[1], educational and training institutions, research and development (R&D) institutions, R&D in important technologies, structure of the industry
Lundvall [LUN 92]	Scandinavian countries	Interactive learning between producers and users	Role of public sector, education, R&D institutions, training institutions, production systems, marketing and finance
Nelson [NEL 93]	15 developed and developing economies	Technological and organizational framework	Activities allocation for R&D, sources of these funds, characteristics of firms, role of industries, universities and government policies

Table 1.2. *Analytical structures of NIS*

Apart from these three conceptual structures, other works have naturally contributed to expanding the NIS sphere. Their reach lies as much on theoretical aspects [MON 01] as

1 Ministry of International Trade and Industry.

on empirical ones [ARC 99]. This being so, far from giving a formal global character to their approach, the multiplicity of words, the operation and the theoretical foundation of researchers would inevitably make certain characteristics of the approach equivocal, inaccurate and sometimes ambiguous.

The interpretation of innovation was defined in especially divergent views. In order to shed light on the number of debates on this subject, most authors made up a dual view by dividing the concept into two approaches: a broad approach and a limited approach of innovation [MYT 01]. We also speak of an organizational versus cognitive approach [HAU 99], an instrumental versus organic approach [BAA 04] and an American versus European approach [SPE 00]. These highly Manichaean approaches enable the authors to directly place themselves within an approach methodology based on the object studied.

Limited approaches are generally associated with the works of Nelson [NEL 93] and Mowery and Oxley [MOW 97]. According to them, innovation is defined in a limited manner, as the dynamics of national innovation are measured only in terms of the formal R&D activities and scientific activities. While innovation can have a radical or incremental character, it only revolves around knowledge creation activities. The main strength of "narrow" NIS lies in the analysis of the impact of national technology policies on the innovative behavior of firms. This NIS only includes organizations and institutions necessary for research and exploration activities, such as R&D departments, technological institutions and universities.

Thus, we look at the narrow NIS as a system integrated with economic and institutional actors who produce the output and use of innovation directly. In these terms, the influence of the "triple helix" concept [ETZ 00], where companies, governments and universities are the main axes

of the interactive dynamics, is especially striking. The same is true of the OECD approaches [OEC 12], which define the NIS in a "narrow" context by five key actors: government, institutions, enterprises, universities and other public and private organizations (public laboratories, training and technology transfer organizations, etc.).

Main features of innovation	Narrow NIS
Nature	Technological and organizational
Character	Incremental and radical
Representation	Creation and use of knowledge
Actors concerned with innovation processes	Actors directly related to science and technology: companies, government, universities
Empirical objects	R&D expenses, R&D staff, R&D organizations, patents, strategic management, public perception of science and technology

Table 1.3. *Narrow conceptualization of NIS*

In contrast, a wide, cognitive, organic and European approach was developed because of the works of Lundvall [LUN 92, EDQ 97, MUC 16, ARO 15]. According to Lundvall *et al.* [LUN 02], Freeman and Lundvall's [FRE 88] versions describe the innovation system (IS) in a broad conceptualization. Innovation, be it radical or incremental, is a continuous cumulative process inherent in the dissemination, absorption and utilization of knowledge. In this version, the emphasis is placed on learning processes, which imply that the competitiveness of individual firms springs from their ability to learn. According to this definition, the interactions between different functions of a company (science, technique, production, commercialization) and between companies and their environment determine a specific method of regulation and overall consistency.

In a macroeconomic context, the broad definition includes indexing the components of the narrow NIS, all political, social, economic and cultural institutions that influence learning, research and exploration activities: financial systems, monetary policies, internal organization of private firms, preuniversity education systems, job markets, etc. In this regard, the works of Amable *et al.* [AMA 97] on social systems of innovation rely on a descriptive view of seven subsystems inherent to innovation processes: science, technology, industry, human resources, education, training and the financial system. These works and the ones that followed them [AMA 97, AMA 02] analyzed the diversity of capitalism, where learning is determined by internal and external conditions in which economies find themselves.

In a more microeconomic level, the strength of NIS lies more in the efficiency of firm networks, the intangible strengths and the varied interactive learning sources within buying, producing and selling activities than on actual R&D activities.

Main features of innovation	Broad NIS
Nature of innovation	Linked to learning processes
Character of innovation	Incremental and radical
Representation of innovation	Knowledge dissemination, absorption, utilization and creation
Actors concerned with innovation processes	Actors directly and indirectly linked to science and technology
Empirical objects	Job markets, financial systems, education systems, cultural values and social cohesion, learning models, links and resources, etc.

Table 1.4. *Broad conceptualization of NIS*

Finally, the "narrow" system is enshrined in a broader socioeconomic system in which political and cultural influences help determine the direction and success of innovative activities. As for selecting approaches, according to Viotti [VIO 00, p. 1], "The large majority of NIS's studies are focused primarily on scientific and technical activities aimed at innovation, especially, with R&D". In other words, the NIS approach would only develop a narrow vision of institutions in its general model. In fact, there are many studies that accept a narrow conceptualization of NIS because of the availability of quantitative data that facilitates empirical work and the nature of political considerations regulated by conventional aspects (for example, budgetary allocations) [BAA 04]. Far from confirming this, Balzat and Hanush [BAL 03] showed the opposite: that the innovative activity in the NIS approach is for the most part analyzed through a broad concept.

According to Lundvall [LUN 92], a narrow[2] definition of innovation, in the strictest sense of the word, characterizes the "narrow" approach and a broader definition characterizes the "broad" approach. Johnson *et al.* describes innovation in the following terms: "The definition of innovation is broader (with reference to the limited approach). Innovation is seen as a continuous cumulative process involving not only radical and incremental innovation but also the diffusion, absorption and use of innovation" [JOH 03, p. 3]. This expression clearly shows that Nelson excluded the dissemination and use of knowledge processes from his definition of innovation. Nelson, who is often labeled the bearer of a narrow conceptualization, does not seem to have theoretically built a narrower approach: "Innovation encompasses the processes by which firms master and get into practice product designs and manufacturing processes

2 Innovation is directly linked to knowledge creation and R&D.

that are new to them, whether or not they are new to the universe, or even to the nation" [NEL 92, p. 365].

This is how Nelson's representation of innovation reflects the broad approach and also touches upon perspectives of production and dissemination of knowledge: "In Nelson's view, the study of innovation should therefore include its generation and diffusion" [CHA 04, p. 15]. The same goes for Mowery and Oxley's NIS [MOW 97, p. 154]: "Creation of a domestic 'absorptive capacity' is essential to an economy's exploitation of technologies transferred from abroad. This capacity includes a broad array of skills, reflecting the need to deal with the tacit components of the transferred technology".

The representation of innovation is not limited to creating knowledge but includes absorbing and diffusing knowledge. For most authors, innovation encompasses all the elements of the Schumpeterian trilogy: invention, innovation (*sensu stricto*) and diffusion. In this sense, the theoretical boundary between the broad and narrow visions loses its coherence.

In the same perspective, another problem arises in terms of the nature of innovation and calls for terminological clarification. Innovation in the NIS is not limited solely to technical innovations[3]. While the narrow NIS directly refers to technological innovation, the broad NIS, in its definition, accepts institutional, organizational and social innovation. But again, the credibility of the broad/narrow approach is called into question. For instance, Nelson's NIS draws on organizational and institutional elements in its conceptualization. While these elements have traditionally been perceived in a narrow sense[4], they go beyond the

3 Thus, we speak of a coevolution of technology, organizations and institutions or a technoeconomic paradigm [DOS 88].

4 Nelson's institutions take a formal connotation and are confused with organizations.

classical system of R&D: "The broad concept of innovation that we have adopted has forced us to consider much more than simply the actors doing research and development" [NEL 93, p. 5]. McKelvey [MCK 91, p. 133] added the following elements too: "Elements included in this are the nature and the effectiveness of the national education, learning, and training system, work relationships as work management models […], characteristics of financial institutions and organizational paths of firms". The elements that he accepts are "broad", so to speak, while the cognitive benchmark of Nelson's NIS is linked to technological innovation.

Even though there are numerous deciding factors of innovation according to Nelson, it is a narrow concept of innovation: "Most of our authors [in Nelson's work] were able to tell a pretty coherent story about innovation in their country focusing largely on institutions and mechanisms that fit the narrow definition" [NEL 92, p. 367]. From the opposite perspective, approaches with narrower deciding factors that directly deal with non-technological innovation would be likely to be classified as broad approaches.

This would be the intended analytical purpose (technological innovation versus cognitive organizational innovation) that would distinguish the broad approach from the narrow approach and not its deciding factors and innovation sources. This being the case, there is a lot of confusion surrounding it. Examples attest to this. Viotti's approach is built on a broad conceptualization of NIS [VIO 00], although she only focuses on technological innovation.

Similarly, Laredo and Mustar's work on innovation and research policies opted for a broad version of the NIS, which, according to them, is linked to that of Nelson's and to technological innovation. Also, in an effort to make the approach intelligible, some authors prefer to directly

mention the nature of the innovation in the approach in order to clearly identify the appropriate methodological tool.

In its terminological variants, the IS accepts a technological system [CAR 95], a national system of science and technology [MAS 98], a national system of technological capacities [LAL 00] or a national system of technological learning [VIO 02] as "narrow" approaches; and a social system of innovation [AMA 97] or a national system of innovation and construction of competencies [MUC 03] as broad approaches. The cognitive mark is directly indicated, which helps avoid terminological confusions and leads us to directly assume the kind of approach used.

Beyond the elements specifying the flexibility of the NIS concept, some similar traits can be easily identified.

1.1.2. *Common characteristics of NISs*

Among the chosen elements, it would be unwise to not first think of the systemic and national nature of the NIS. Also, while the conceptualization of innovation is the subject of many debates in the approach, the national and systemic attributes, without which the NIS would have not have arisen, are evidently commonly accepted.

Moreover, innovation, in its national limits and its systemic specificities cannot exist without appropriate components. Although these components were briefly mentioned in section 1.2.1, they deserve more attention. Identifying the approach through its components is still a major element in an empirical construction perspective.

The national framework constitutes a natural limit of ISs. Nevertheless, the approach to ISs is obviously much broader and accepts as alternative frameworks [GRE 97]:

– sectoral systems concerning a sector or a specific technology [BRE 97];

– localized systems, built on spatial proximity and identifiable across multiple geographic levels, at the local, regional, national or global level [LUN 92, NEL 93].

Usually, it is the field of empirical analysis that defines the boundaries of the system at the conceptual level. In other words, the IS has a specific name suitable to the purpose and context analyzed. From this perspective, the relevance of the national framework is related to a number of empirical studies whose conclusions tend to show the following points [LUN 98]:

– national production and ISs are specialized and have few converging signs;

– multinational firms are expanding internationally, but a number of their activities remain domestic;

– the diffusion of innovations and the use of new technologies are becoming more international, but domestic markets play an important role in promoting innovation.

The nation-state system is undeniably coherent despite the free movement of information, knowledge, finance, goods and services, which does not prevent strong national differentiations between institutional support, R&D investments and technological performance of various countries [NEL 93]. However, other arguments need to be researched to better understand how national NISs are [BAL 03]. Lundvall [LUN 92] justifies the national framework with reference to the political, historical, cultural and social importance of the IS. Historical evolutions, cultural models, socioeconomic structures, political styles, laws, traditions and governance models are all specificities and different national representations. These references do not call into question the various elements of innovation processes that

tend to become global[5]. This is why NIS is often called "open national innovation systems"[6] [BEL 94].

Moreover, while the NIS develops within national borders, it finds coherence from collective learning mechanisms. Without collective devices, it is difficult to accept the existence of an IS [ARC 98]. The *raison d'être* of the NIS approach lies above all in the fact that innovation is an interactive process whose scope depends on the type of relationships between different firms, organizations and institutional behaviors in production, diffusion and use of new knowledge.

Many formal and informal cooperations by networking between scientific, industrial, institutional and service sectors are of interest to the development of innovations.

Figure 1.2 shows the above aspects.

The connections and interactions within and between the sectors represent the real information and knowledge flow, and are defined as important mechanisms for the transfer of tacit and codified forms of knowledge (see Box 1.1). These tangible or intangible flows include financial flows between governments and private organizations, human flows between universities, firms and government laboratories, regulatory flows of government agencies toward organizations as well as knowledge flow between institutions [NIO 02].

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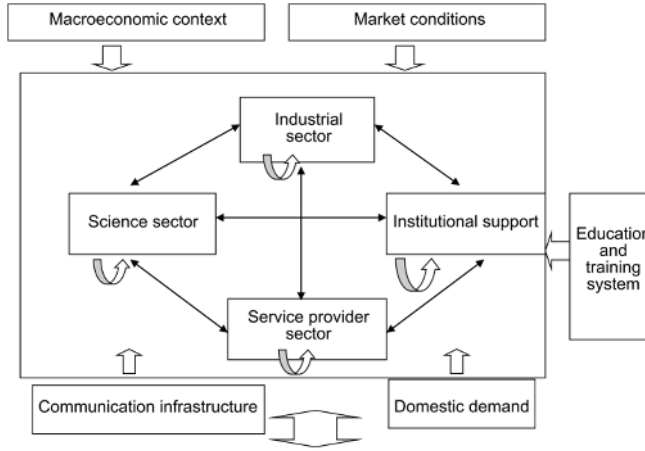
5 Innovation activities are currently managed by several multinational firms that question the coherence of a *national* system framework [PAT 00].

6 In this regard, Amable *et al.* [AMA 97] proposed a "social innovation system" in order to criticize the hypothesis of the national dimension of an innovation system and to expand it using an analytical methodology leaving open the question of the space in which it functions.



Macroeconomic context: Internal overall environment: intellectual property rights, legal system, trade and technology policies, and overall external environment: influence of the internationalization of economic activities on domestic firms.

Communication infrastructures: Telecommunications networks, role of new information and communication technologies.

Education and training system: Quantitative and qualitative aspects of the overall education system: degree of elitism versus egalitarianism, role of job markets.

Domestic demand: Influence of the internal market and non-market collaborative relationships between producers and users of technology.

Market conditions: Technical skills, financial activity to promote the technology sector, and access to local and foreign information.

Industrial sector: Industrial firms and laboratories indexed to R&D.

Science sector: Universities and public or private research centers.

Institutional support: Interfaces between the innovation system actors. It can be formal: employer groups, legal and regulatory or informal structures: conventions and norms influencing the behavior of companies.

Service sector: Assistance and support to industrial firms: consultancies, legal expertise, training and marketing related to new technologies.

Figure 1.2. *Flow and interactions in NIS*

However, while innovation in NIS approaches is recognized as an interactive process, the degree of interactivity is generally determined by the existing structure of the institutional framework rather than by the articulation of strategies of firms in the systemic context[7]. In other words, the NIS approaches tend to support *broad devices* linked to the institutional performance of actors more than *selective processes* based on the microeconomic determinants of innovation [MON 01].

Archibugi *et al.* [ARC 98] compare the top-down perspective in which institutional structure and policy choices determine the learning trajectory of economic agents, with the bottom-up perspective that tries to understand how the microdiversity of decisions and components of firms influences NISs. This especially favors processes, links and interactions in order to ascertain the ability of firms to face innovation problems in a specific context.

Innovation combines two types of knowledge: codified knowledge (explicit) taken from previous experience and tacit knowledge (implicit) specific to a form or an individual. Tacit and codified elements combine in each technology. According to Karl Polanyi [POL 66], the tacit nature of knowledge refers to elements that are undefined, non-codifiable, not fully articulated and difficult to transfer, which differ from one individual to another, but can still be shared between collaborators with a common experience. Tacit knowledge is set within organizations, individuals and regions [LUN 01]. Explicit knowledge is produced through R&D activities within firms or external actors, and is expressed through a formal language in the form of date, scientific formulae and manuals.

Knowledge sharing is rarely fully tacit or codified. It often falls between the two. Neither is knowledge directly codified, remaining tacit in the minds of those who created it. Codification is always indispensable, as knowledge creation is a collective process that gives rise to complex communication and transfer mechanisms. Currently, knowledge accumulation is becoming increasingly based on a firm's

7 Few studies try to link firms' strategies to the systemic context of interactive innovation processes.

experienced, skills and capacities, as well as on its reputation and trustworthiness. This favors tacit components, based on common practices of modes of interpretation, perception and value systems, all of which cannot be transferred through face-to-face interactions between partners who have the same languages, codes, norms and common conventions. Thus, the organizational capability to create knowledge is the key element in firms' competitiveness.

With this in mind, Nonaka and Takeuchi [NON 95] recently proposed a model describing knowledge production in a firm. Their work, titled *The knowledge-creating company,* is based on the interaction between tacit and codified knowledge. The organizational knowledge creation, a true reflection of the importance of institutional learning processes, includes two types of interactions: those between tacit and explicit knowledge, and those between individuals and organizations.

The interaction between the two knowledge types is key to the dynamics of knowledge creation. Four modes of knowledge conversion have been identified by them. They involve specific learning processes:

– from tacit knowledge to explicit knowledge: *externalization* is essential to knowledge creation because it generates new explicit concepts from tacit knowledge. Codification is at the heart of this mode;

– from explicit knowledge to tacit knowledge: *internalization* is linked to learning through practice and creates operational knowledge;

– from tacit knowledge to tacit knowledge: socialization is related to various experiences that create new tacit knowledge like technical skills, for instance;

– from explicit knowledge to explicit knowledge: *combination* is the process that requires the encounter of different explicit knowledge with the aim of creating a new systemic knowledge. This mode is found in the training and education of employees.

Box 1.1. *Innovation, tacit and codified knowledge*

ISs are made of links and elements in a specific environment [CAR 02]. This composition also applies to NIS that develops within organizations, interactions and an appropriate institutional environment.

The difference between institutions and organizations was presented in the works of North [NOR 90) as well as those of Lundvall [LUN 92] and Edquist [EDQ 97]. However, although this difference is mostly accepted, it does not operate unanimously[8]. Institutions are described as formal and informal standards offering adequate structure and favoring interactions between members of the society. Overall, they are defined as the rules of a game in a society [NOR 90]. In particular, economic institutions are norms that establish *ex ante* economic action, serve as evaluation criteria of the *ex post* economic action and create confidence in economic interactions. Furthermore, they guarantee, define and guide the functioning of the market.

Innovation is built around the institutional structure of the economy. This is what creates a model of constraints and incentives that shape and channel actors' behaviors. They traditionally attributed two functionalities: a behavioral dimension, due to their *ex ante* instructive nature, and a normative function, due to their *ex post* bases of evaluation. Examples of formal institutions are laws, directives and regulations, while among informal institutions, we have norms, habits, practices and routines as well as, for instance, the role of confidence and the mixing of rationale [LUN 98].

Each institution plays a specific role in the NIS by the distribution of compatible procedures and standard practices that structure the relationships between individuals. As a result, institutions simultaneously create order and continuity, while having an impact on the conduct and

8 Several authors use the term "institution" to refer to institutions and organizations. This reasoning is strongly criticized: "It seems as if most innovation theorists think of institutions in accordance with the everyday meaning of the term […] This way of using the concept of institution is not based in institutional theory – or any other theory" (Edquist, Johnson, 1997, p. 43).

performance of the IS [LUN 02]. Moreover, institutions evolve without being static and without optimal institutional frameworks. These are, however, specific to the countries in question, and their configurations depend on political, social and cultural contexts. Also, institutions are difficult to transfer from one country to another.

As for organizations, they are embedded within a specific institutional environment. They are defined as structured and institutionalized systems built to perform a certain number of tasks. They represent, among other things, companies, research centers and universities.

The NIS concept brings together various attempts to incorporate institutional, organizational and interactive behavior elements within a preestablished territorial framework. But, although the approach is made up of definite representative pillars, it does not make any convincing established and consensual proposals. NIS is constantly adapting according to each case. It thus seems to be a conceptual structure and not a formal theory [EDQ 97].

1.2. NISs of the Southern Countries: emerging economies and economic development

Although it is increasingly frequent [MUC 16, ARO 15], the idea of developing the concept in the economies of the Southern Countries is not recent, as Nelson [NEL 93] showed in the third section of his book.

The following taxonomy identifies four types of economies: from the most developed, commonly called the Northern Countries, to the least developed, called the Southern Countries. While it is questionable due to its simplistic nature, we will use this narrow classification to focus our empirical analysis to the case of emerging economies and call all the NISs including those of emerging, developing and

least developed economies (LDEs) as "Southern Countries" NISs.

Least developed economies	Developing economies	Emerging countries	Developed economies
Countries corresponding to the criteria defined by the UNCTAD for population, low income and lowest human development index	Countries changing from a chronic underdeveloped state to a kind of development process	Countries with a good economic growth but showing signs of different weaknesses	Countries with most of their population having access to all basic needs
Burkina Faso, Cameroon, Ethiopia	Peru, Bolivia, Thailand, Argentina	Mexico, Indonesia, Turkey, Nigeria	France, United States, Japan, Germany

Table 1.5. *Identification of the nature of economies*

The "least developed economies" constitute a category of countries created by the United Nations Organization in 1971 to classify all the LDEs. They have the lowest human development index and must thus get special attention from the international community. Most are failing states. In 2017, 48 countries were considered as LDCs, most of which are situated in Africa and particularly in sub-Saharan Africa.

There is no actual and official definition of the notion of "developing economies". This intermediary status between the LDCs and developed economies is characterized by the

engagement in a process to raise the living standards, economically and socially, of its inhabitants by trying to end, in particular, the low development of industry, insufficient agricultural production, imbalance between rapid demographic growth and increase in its national income. Many Latin American countries come under this category.

Finally, emerging countries cover a wide variety of situations. Belonging to this group is not fixed. However, we can recognize some common criteria among all the countries of this group such as a high growth rate, a strong demography or an increasing share in the global economy. Thus, these are countries that tend to have several indicators (especially economic ones) on a consistent rise and which are progressing toward becoming a part of the developed economies group, despite some signs of internal instability. In this group, we can find China, India, Brazil, Pakistan, Malaysia, the Philippines, Iran, etc. While we spoke of "new industrialized countries" as intermediate or emerging countries represented by the "Four Asian Tigers" (South Korea, Singapore, Taiwan, Hong Kong) in the 1960s, emerging economies were mostly strengthened by their inclusion into international trade and huge institutional reforms (these include Argentina and Thailand).

Meanwhile, developed economies are countries where the majority of the population has access to all basic needs as well a certain level of comfort and education.

Thanks to the flexible nature of the NIS and the possibility of expanding its contents, no element can limit NIS to only developed economies. But several limitations have nevertheless made the study of the NIS more delicate in the Southern Countries. In an empirical context, insufficient data and lack of information have limited the observation of these NISs. In an ideological context, the main reason resided with the scope of research that could seem *provocative* [JOH 03] with regard to the fundamental priority issues such as

poverty and democratic instability. Yet, innovation and learning are tools for fighting poverty and represent the major elements of the economic development of countries [LUN 02]. Poverty reduction and improving income distribution are firmly connected to the capacity of developing economies to master the use of knowledge.

At this level, therefore, the NIS in the Southern Countries will move toward a broad conceptualization. Also, two kinds of answers are presented to the question, "Do national innovation systems exist in developing economies?" [NIO 92]: the answer that more or less tacitly mentions the *de facto* existence of NIS [ALC 98] and that which highlights the non-existence [ARO 03] or, at least, the different conditions for emergence. Considering interactional deficiency between key components of the NIS in the Southern Countries, the second solution is without a doubt the most coherent in those economies. Let us identify the characteristics of the Southern NIS (section 1.2.1), before understanding how these NISs address economic development issues (section 1.2.2).

1.2.1. *NISs of the Southern Countries*

The NISs of the Southern Countries have several distinctive characteristics. However, far from being fundamentally atypical, they have characteristics in common, because of their origin, with the developed NISs: "the national innovation system concept has been developed from various structures of developed economies" [GU 99]. First, there appear to be characteristics similar to those of developed economies, among which we have nine elements of the NIS approach identified by Edquist [EDQ 97]:

– the NIS places innovation and learning processes at the heart of a learning economy (see Box 1.2);

– it adopts a holistic and interdisciplinary perspective;

– it uses a historical perspective to the approach and considers innovation processes as evolutionary processes;

– it accentuates the differences between systems and rejects the notion of *optimum*[9];

– it highlights the interdependence between systemic components defined as real actors;

– it includes innovation processes and products as well as their development and diffusion;

– it highlights the central role of institutions as rules of the game;

– it emphasizes its diffuse nature;

– it represents a conceptual structure rather than an actual formal theory.

The learning economy is an interpretation of the current contemporary economic concept.

Introduced by Lundvall and Johnson [LUN 94] and incorporated in numerous works [LUN 97], this economy means that current change does not reside in the intensive use of knowledge but rather in accelerating the speed of change that leads to rapid depreciation and obsolescence of qualifications and knowledge. This rapidity of change is especially linked to the diffusion of information and communication technology, and the expansion of the international market.

Therefore, the essential competitive factor of firms resides more in the ability to acquire new skills rather than in the retention of some knowledge or in access to information.

The ability to learn and adapt to the current context is crucial for the performance of individuals, firms, regions and countries. It defines a constant need to rebuild the qualifications of individuals and the organizational and technological skills of firms. This implies a broad definition of knowledge and learning.

Thus, actual creation of knowledge includes various practical skills through learning by doing as well as intellectual abilities acquired in education and training institutions. It also includes managing the

9 This concept is related to the normative dimension of NIS.

knowledge of firms through organizational learning as well as new R&D perspectives.

The learning economy must not be confused with an information economy.

Information is a part of knowledge that can be easily transmitted through computer networks, while learning is largely based on the know-how, i.e. on the ability to know how to do something, which requires tacit skills and qualifications that cannot be transmitted by telecommunication networks.

The learning economy cannot be likened to a knowledge economy. Learning is a flow, while knowledge represents a stock.

In this sense, the learning economy prevents an analysis specifically based on institutions and includes the production and distribution of knowledge (research centers, universities, educational institutions), and also learning by routine.

Moreover, the learning economy directly focuses on training new resources leading to innovation. In this, it analyzes economic structures and institutional frameworks affecting learning processes.

As for the knowledge economy, it focuses more on understanding economic growth in the long term and is based mainly on the allocation in existing resources (knowledge stock).

Finally, the learning economy differs from the neoclassical economy on several points: technologies are similar to flux that continuously follow learning and re-learning trajectories. These learning processes are likely to improve the skills of actors.

Furthermore, the merit of this theoretical proposition resides less on the allocation of resources than on the creation of new values, products and services. Also, the evolutionary economy is a key alternative of the NIS approach when it uses the concepts of variety, selection and reproduction as relevant elements for the analysis of innovation and learning.

Box 1.2. *The Learning Economy*

Elements more specific to the NIS of the Southern Countries are highlighted by Edquist [EDQ 97]. Depending on the nature of the economies studied, mention is often made of several organizational and institutional rigidities

linked to IS development paths, and also the maladjustment of macroeconomic policies, low investments in education and R&D, difficult integrations of NIS in the global economy as well as their low technology assimilation and production. The NISs of the Southern Countries are generally portrayed from their various systemic failures [EDQ 01]. In light of all these considerations, it becomes difficult to speak of the *a priori* (*ex post*) nature of NIS, which is used in order to empirically analyze and describe innovation processes of industrialized countries with a strong institutional base and advanced infrastructure. The NISs of the Southern Countries, rather, have an *a posteriori* (*ex ante*) nature so that analysis can be more upstream on its emergence and development conditions. This is an important point, as it shows that the NIS does not exist as such in the process of emergence, but that, *in fine*, the dynamics of learning and systemic interactions enable the development of an NIS.

Another element: innovation, as the ability to create new products and processes, is less important than the ability to use and adapt existing technologies at competitive levels in terms of cost and quality [LAL 02]. Innovation is no longer on the border of technology but includes catch-up strategies implemented by lagging countries. While technological absorption and learning take place at the level of the firm and the central objective of other actors of NIS is to promote the ability of firms to innovate, the success or failure of these firms is orchestrated by the entire system [KIM 97].

Then, there is the heterogeneity of development trajectories. Work on the NIS of the Southern Countries tends to accentuate the multiple differences between national systems and enhance the various stages of development achieved by these systems. This leads to the idea that the NIS of the Southern Countries involves catching-up strategies of lagging countries by developing technological capabilities.

In a very different perspective, the NIS approach in developing countries enhances innovation processes in low- and medium-tech sectors without limiting it to high-tech sectors [JOH 03]. While innovations in high-tech sectors are sophisticated and based on science and radical transformations, the NIS in the Southern Countries is a reflection of routine learning perspectives within small traditional businesses.

Furthermore, it should be stressed that the NIS in the Southern Countries is fundamentally *relational* [ARO 02]. Beyond the normative design of the NIS, the literature on the NIS of the Southern Countries tends to highlight the importance of collective and informal connections between actors. There is a fourth indispensable element to understanding the NISs of the Southern Countries: social capital formation. While Lundvall *et al.* [LUN 02] initially showed their commitment to the notion of social capital as a vector of performance in Scandinavian countries, Arocena and Sutz [ARO 03, p. 7] directly applied and analyzed the above notion in the NISs of the Southern Countries: "The connection [with social capital] should deserve great attention in Southern Countries". According to them, if the NIS of the Northern Countries is competitive, it is due to high pre-existent social capital. Building innovation results in the institutional framework that is highly imbued with the society itself.

In this context, the significance of social capital is reminiscent of that of the informal in the NISs of the South. Innovation in developing countries is mostly conducted informally by techniques of learning by doing, using and interacting. R&D activities are not clearly and formally articulated within the strategy of the company [ARO 99]. Gradually, the idea, according to which informal endogenous cells had a well-defined place in the NIS on the South, was accepted.

A final distinctive element of the NIS of the Southern Countries is revealed: global technological environment. Literature on ISs pays little attention to vulnerability and instability problems related to the macroeconomic, political, institutional and financial environment. These problems are still prominent in the problematics of developing countries[10] [CAS 99]. To conclude, the group of major features of the NIS of developing countries has the following characteristics.

Characteristics of NISs of developing countries	Representation of NISs of developing countries
A posteriori nature of NIS	Conditions for emergence of the NIS in the South
Technological capabilities	Technology absorption and diffusion process, incremental innovation
Heterogeneity of development trajectories	Study of various stages of development, contribution of lagging countries' catching-up strategies
Innovation process in low and medium tech	Broad representation of innovation across low and medium tech
Relational nature	Highlighting interactive processes
Place of social capital	Significance of social links, norms and networks
Place of informality	Significance of informal endogenous technologies
Global technological environment	Considering local and international context

Table 1.6. *Common features of Southern Countries and emerging NISs*

To innovate, the economic actors need to respond intelligently by adapting with agility to the new evolutionary

10 Here, we speak of a "national system of inertia" [HOB 04] in developing countries in order to highlight social, political and technical problems faced by these countries and looked at as a major hindrance to innovation.

conditions of the market and their institutional, cultural and social specificities.

To do this, they must constantly discover new sources of learning, specific to their culture, in order to meet local needs and improve the quality of life of the population. Innovation in the South is quite often built in *conditions of scarcity* (see Box 1.3).

Learning in conditions of scarcity is a paradigm presented by Arocena and Sutz [ARO 01] in order to highlight the ability of actors of underdeveloped countries to overcome the difficulties encountered in routine activities and innovate in idiosyncratic paths. The ability to innovate in conditions of scarcity especially relates to the specific problems of poor countries and problems specific to poorly educated human resources.

Scarcity refers to a number of missing inputs: financial resources, demand for knowledge, availability of physical instruments, intermediate goods, deficient institutions, etc. This scarcity does not imply that technological abilities are non-existent in developing economies.

On the contrary, here, innovation is no longer alleged and does not refer to available resources but to a specific given environment. Innovation emerges from the lack or inadequacy of inputs. Thus, it is recognized that some problems can be solved in developed economies while being out of reach in underdeveloped economies. And this is with regard to the restriction of resources and many conditions of scarcity.

But while the scarcity prevents innovation in a Westernized, standardized and canonical conceptualization, it can stimulate new avenues of creativity.

Conditions of scarcity are thus the basis of new idiosyncratic trajectories of problem solving. No solution to the problems can be imposed from the outside and no one initially has the ability to solve given problems. Learning in conditions of scarcity involves the ability of the actors to find solutions to problems when faced with technical, economic and cultural constraints. This learning requires skills of imitation, interaction and resolution of local problems. It is based on the diversity of solutions given to the envisaged problems.

Box 1.3. *Learning in conditions of scarcity*

1.2.2. *NISs and economic development*

NISs address growth and economic development issues. In this, two aspects are particularly important in the issue of the Southern NIS (emerging and developing): promoting learning culture and promoting inclusive ISs.

1.2.2.1. *Promoting learning culture*

"Learning culture" refers to the daily promotion of learning in all segments of the economy (R&D, production, human resources, institutions, politics), from individual learning to organizational, tacit and explicit, formal and informal learning in low and medium tech, exact sciences to the humanities. This notion requires adapting knowledge to local conditions and improving the latter in the whole economy [LUN 02a]. It is through the fragile development of this learning culture that "learning capabilities are limited and that the institutional framework does not perfectly know how to promote the necessary learning" [JOH 03, p. 17].

Learning is the key element of the strategy of firms and organizations. The diversity of learning sources does not seem to be valued enough in NIS approaches [JOH 03, p. 9]:

> "… What is missing in the capability based approach, as well as more generally in development theory, is a focus on learning capabilities as a whole; the many different kinds of learning, which are going on in society, i.e. in rural areas, villages, firms and organizations in the public sector as well as the private. Only a part of this takes place in the formal education system or in the research system. What needs to be understood is how and to which extent individuals, communities, firms and organizations are geared to learning and innovation, either by themselves or in interaction with others".

Traditional and tacit knowledge is often representative of the societies in Southern Countries. As in most developing countries, learning is mainly internally and informally driven and R&D activities are formally articulated in the company's strategy. The learning is therefore not only assimilating the formal production of science and technology. Furthermore, learning cannot only be viewed as learning by doing, when problem solving in the South is but a mix of imitation techniques and the creation of new paths as an alternative to failing factors [ARO 01]. Learning sources are very broad. For example, Oyelaran-Oyeyinka [OYE 97] demonstrated the existence of seven channels of learning in Nigeria: learning by training, on-site training by suppliers, on-the-job training, business experts, support mechanisms for learning from public institutions, learning through transaction with local or external agents and learning through practice in production and maintenance activities. These different modes of learning alternate according to the nature of the business, its internal culture, its existing abilities and its socio-cultural environment (see Box 1.4).

Innovation is the process of technical change achieved by the introduction of a new product or process of production (new to the world and not to the firm, country or region).

(An innovator usually masters the capability to innovate, as well as the capabilities of production and improvement.)

Technological learning is the process of technical change achieved by:

– absorption of technology already acquired, namely the absorption (diffusion) of innovations produced elsewhere;

– improvement of technology already acquired, namely incremental innovation.

Passive learning is the process of technical change achieved by:

– the forms of technological absorption with minimal technological effort (minor adaptations to local conditions);

– the type of incremental innovation achieved as an almost automatic and costless consequence of experience acquired in production.

(A passive learner is satisfied with just the acquisition of the capabilities for production.)

Active learning is the process of technical change achieved by:

– technological absorption accompanied by efforts to master the assimilated technology (major adaptations to local conditions, permanent training);

– the type of incremental innovation achieved as a consequence of deliberate efforts and investments in technology.

(An active learner develops capabilities of improvement, besides the capabilities for production.)

The main *technological capabilities* are:

– *innovation*: knowledge, skills and other conditions required for the creation of new technologies, i.e. major changes in the design and core features of products and production processes;

– *improvement*: knowledge, skills and other conditions required for the continuous and incremental upgrading of product design and performance features and of process technology;

– *production*: knowledge, skills and other conditions required for the process of production.

Box 1.4. *Innovation and learning (source: [VIO 03])*

1.2.2.2. *Promoting inclusive ISs*

While innovation has been introduced into development theories and economic development in the SNI approach [DUT 14, CAS 15], the fact remains that innovation in the South must take an inclusive approach through the democratization of knowledge.

This democratization of knowledge involves taking social policies into account in innovation policies [CAS 17, DUT 14], and also recognizing education systems, reducing inequalities, and fighting against poverty in the NIS approach. Systemic processes interact with institutions in which civil society plays a key role. The point is not to undervalue the role of the state or market relationships, but to imagine civil society as representing an *environment of virtuous and disinterested*

cooperation [DUT 14, p. 30]. The interactions present in an NIS depend on the power relations of the actors participating in the innovative processes. The configuration of NISs is not socially neutral. It often acts in conflict. Therefore, an NIS develops if socially constructed networks are beneficial to the creation of skills within a national structure.

For example, the links of education systems are an essential entry into the NIS approach [CAS 14]. The concept of *developmental university* [ARO 07] shows the interest in overlaps between higher education and societal issues in the broad sense. Table 1.7 shows the questions arising between the university system and society with the aim of achieving a systemic construction of innovation.

Main features of developmental university systems	Key objectives	Aspects related to defined objectives
The universalization of lifelong education	Eliminating registration gaps between North and South	How do universities cooperate with other organizations to create a broad higher education system that offers learning opportunities to the majority of the population? What efforts have been made, theoretically and empirically, to face the challenge posed by lifelong learning? To what extent does higher education create links with productive systems?
A research activity linked to development imperatives	Steer research activity through elements of social inclusion	How does the university system function as an information collector for the development of inclusive research or technological creation? Are interactions with the whole society properly implemented?

The global diffusion of the *developmental university*	Encourage student participation in productive and social issues	Does research in all its components attract sufficient attention, particularly in the social sciences and humanities?

Table 1.7. *Characteristics of the developmental university system (source: adapted from [ARO 07])*

Aspects	Measures	Capability
Science, research, innovation	Scientific publications, patents	Technological
Openness	FDI, licenses, immigration	Technological
Quality of production/standards	International standards (ISO)	Technological
Technological infrastructure	Telecommunications, Internet, computers	Technological
Capabilities	Primary, secondary and higher education, managerial and technical skills	Technological and social
Finance	Access to bank credit, venture capital	Technological and social
Quality of governance	Corruption, laws, independence and separation of powers, property rights, regulation	Social
Social values	Civic activities, trust and tolerance	Social
Type of political system	Political rights, democracy	Social

Table 1.8. *Capabilities and NIS (source: [FAB 08])*

In this dimension, an article by Fagerberg and Srholec [FAG 08] shows the link between the NIS, economic development and the notion of capabilities [SEN 03].

Fagerberg and Srholec propose to empirically identify capabilities from the elements presented in Table 1.8.

From these proposed elements, and through a proposed regression model, the authors conclude that the catching up of countries of the Southern Countries is based on four essential elements related to the development of ISs, the quality of governance, the character of political systems and the degree of openness of trade relations and foreign direct investment. This demonstrates the importance of technological and social capabilities in the construction of Southern NIS. Encouraging actors to have a positive attitude, while most of them do not have confidence in institutions, can contribute to "Sen" development as an *end* and the *means*: *end* as in objective (poverty reduction) and *means* as a process in which individuals must succeed (through a democratic framework, for example).

The NIS must also be able to answer to issues of inequality and the fight against poverty. Narayan and Petesch [NAR 02] show how listening to poor countries is imperative for linking innovation and development in developing countries. It is not a matter of listening to the voice of Western countries on the policies to be followed, but rather of highlighting the societal problems of civil society [DOL 04]. If this is the case, the emergence of informal ISs would gain legitimacy, as Müller showed in Tanzania [MÜL 11]. It would be similar when taking natural capital and environmental issues into account in the NIS approach [SÉG 03].

The result is four types of capital in the Southern NISs: productive capital from the point of view of production systems, intellectual capital through skills and capacities, natural capital with environmental issues and, finally, social capital through social values and trust in networks.

While they are also present in the developed NIS problem, they are especially important in the Southern economies where social capital is often the milestone of market relationships.

	Easily reproducible resources	Hard-to-reproduce resources
Tangible resources	Productive capital	Natural capital
Intangible resources	Intellectual capital	Social capital

Table 1.9. *Economic development through accumulation and utilization of tangible and intangible resources (source: adapted from [LUN 02a])*

Finally, the NIS is built in an inclusive angle by the following definition [JOH 12]:

> "Inclusive development is a process of structural change, which gives voice and power to the concerns and aspirations of otherwise excluded groups. It redistributes the incomes generated in both the formal and informal sectors in favour of these groups and it allows them to shape the future of society in interaction with other stakeholder groups".

This definition is based on a report by the Globelics group. Johnson and Andersen [AND 12] explain the concept of inclusive IS through the recognition of broad ISs aimed at economic development and growth. An increasing number of NIS works put this dimension forward (Table 1.10).

Topic	Work
Inequalities and poverty reduction	Dolla [DOL 04]
Democratization of knowledge	Dutrenit and Sutz [DUT 14]
Inclusion in educational systems	Cassiolato *et al.* [CAS 14]
Recognition and measurement of capabilities	Fagerberg *et al.* [FAG 10]
Taking informal links into account	Müller [MUL 11]
Capacity building as the means and end of development	Lundvall [LUN 02]

Table 1.10. *Inclusive NIS: topics and issues*

1.2.3. *Terminological variants of the IS*

While the IS pursues various objectives according to the desired orientation (growth, economic development, technological performance), terminological variants adapt based on the content that authors wish to accord it. There are three derivatives from the *national system of learning*: Viotti's [VIO 97] *national system of technological learning*, *national system of technological capacities* [LAL 00] and *national system of economic learning* [MAT 99]. Eduardo Viotti, who wrote an excellent thesis on the concept of the *national system of learning* (1997), was the first author to propose a new name for the NIS in developing countries. He took his idea and expanded it in many of his works [VIO 02, VIO 03]. In his articles, he highlights the features of the NIS and technical change in developing countries. He noted three main rationales of the approach: focus on technical change, explanation of the economic performance of nations and the importance of institutions and history. According to Viotti, the NIS is a narrow concept that deftly bypasses technology diffusion processes, which is essential in developing countries. In light of these considerations, he proposes to introduce the concept of *learning*, including

incremental innovation and diffusion, and excluding the concept of innovation, all too rare in developing countries. Finally, he finishes his analysis by connecting innovation, incremental innovation and the process of absorption to three different levels of abilities and types of strategies of firms. Thus, he identifies the *NIS* with the *national system of active learning* and the *national system of passive learning*.

In the same conceptualization of innovation, integrating more political and institutional considerations, Lall [LAL 00] suggests the usefulness of a *national technological capability system* or a national technological system [LAL 03] in developing economies. Highlighting the analysis on the technological development of nations, they describe it as the set of skills, experiences and efforts that allow national companies to buy, improve and create new technology. Lall proposes three identities inherent in the concept, among which are the existence of *institutions*, *incentives* and *capabilities*. While he recognizes that the interaction of economic, political and social factors determines the system within which firms learn and innovate, the "effort" to be put in is technological in nature, even if entrenched in the specific context of each country. Therefore, the indicators they offer to justify their *national technological system* are linked to technology imports, technological institutions and technological capabilities.

Ultimately, Mathews [MAT 99] presents a new concept, that of a *national system of economic learning*, in order to explain the technological development of countries that are catching up by managing technology diffusion. For this, he especially based his analysis on the role of institutions, particularly on organizations, and researched the microfoundations of the technological development of those countries. First, he outlined the similar and dissimilar features of technological development of countries that are catching up, which have substantially improved their skill

acquisition processes by managing technology diffusion rather than creating technology through innovation management. Second, he developed a technology diffusion management model based on learning strategies, multiple channels for diffusion, the dynamics of the processes and the necessary institutional base. To confirm the applicability of his analytical structure, he noted several cases of industrial creation in Korea, Taiwan and Singapore, and suggested a model for analyzing the phenomenon observed in these countries. He even generalized his model not only for developing countries as a whole, but also for some lagging firms in industrialized countries.

Setting aside these different terminologies, we will retain those of Lundvall and the Globelics network as being the most relevant, because they are broader and more adapted to the economies of the South [EDQ 01, LUN 02, MUC 03, MUC 16]. It is this perspective that Edquist [EDQ 01] and Lundvall *et al.* [LUN 02] had when they proposed the *national systems for development* and *national system of innovation and construction of competencies* as new IS terminologies. Lundvall *et al.* [LUN 02] focused on the *national system of knowledge creation and learning* when they tried to expand the analysis of NIS in an economic context of learning with a broader focus on the role of demand. To be more precise, in the publication by Muchie *et al.* [MUC 03], Lundvall *et al.* [LUN 03] justifies their new title in the economies of the South with the following statement [LUN 03, p. 5]:

> "...we need to broaden and enrich the NSI-concept so that it becomes a useful tool for promoting structural transformation. The title of the international conference in Aalborg in 2002 '*African Systems of Innovation and Competence Building*' was chosen to signal such a need to broaden the innovation system approach".

While linear visions of innovation have steered innovation policy toward offer, systemic visions of innovation have given a central role to demand [EDQ 99] while neglecting the diversity of end users [ARO 02]. By presenting the interactive model of innovation, Kline and Rosemberg [KLI 86] were among the first to recognize the importance of *users* in the innovation process. This was not to demonstrate the *demand-pull innovation* hypothesis, but to ensure interest in the additional strengths of different firms as well as the coordination between firms and other actors, which is essential to the development of *innovation chains*.

With this in mind, Von Hippel [VON 88] proposed a model of *distributed innovation process* in which products of innovation come from three sources: suppliers, producers and users. The *lead user* or the sophisticated user has needs in advance of markets and is a "forecasting laboratory" for producers.

In broad terms, interactive learning theories [LUN 92] presented the existence of imperfect markets that meet users' needs for qualitative information. Demand is not only articulated through the market, but takes place through non-market collaborative relationships between individual users and producers of innovation. Users' lack of skills is an actual problem comparable to producers' lack of skills.

As for the many analyses on networks, they too retraced the dynamics between vertical and horizontal collaboration within organizations.

Finally, coming back to the NIS issue, recent works analyzed the role of education systems, job markets and organizational management of firms in order to identify some elements of demand for innovation [BRU 09]. But while users have been highlighted in the NIS approaches, they are still apprehended under strict considerations. The role of universities is often overlooked, as are many users of technological and/or non-technological products and processes in the South, which are outside the traditional field of R&D. Moreover, users are often associated with formal actors, whereas informal users have their place in innovation processes. Finally, users are often evaluated through the learning-by-using process. However, learning by using represents only one of many learning channels in the NIS representation (learning through training [learning by learning], recruitment [learning by hiring], etc.].

Finally, while learning theories definitely lay stress on demand, demand has particularly limited consideration within NISs.

Box 1.5. *NIS and the demand approach*

These terminologies are important because approaches to ISs must be modeled on each country's situation. For this, they require conceptual as well as terminological adaptation. Thus, the expression *national IS* has two definitions (*sensu stricto* and broad) and is likely to hinder the use of the concept when applied to specific cases.

The first definition is related to the conceptualization of innovation strictly limited to science and technology, and the second is expanding the concept into paths appropriate to the objects under consideration. In order to clarify the terminology of the Southern NIS, the expressions *national system of technological capacity* [LAL 00], *national system of technological learning* [VIO 03] and *national system of economic learning* [MAT 01] were meant to emphasize the importance of the capacity to diffuse and absorb existing technologies rather than create new technologies.

These three actors broadened the NIS concept, which, according to them, is globally identified under its strictest form: "The NIS theoretical and conceptual framework is not appropriate for dealing with the processes of technical change typical of industrializing economies, which are extremely different from those of industrialized countries" [VIO 00, p. 2].

Nevertheless, while terminological diversity makes it possible to apply the NIS under multiple angles of analysis, it has only been applied in some developing economies. The problem exists in emerging economies, which are grouped into heterogeneous terminologies with no specific name for their category.

	NIS *stricto sensu* [MAS 98]	Broad NIS without terminological adaptation [ARO 03, DUT 14]	Broad NIS with terminological adaptation [LUN 02, MUC 16]	National System of Technological Learning [VIO 03]	National System of Technological Capacities [LAL 00]	National System of Economic Learning [MAT 99]
Characteristics of NIS approach	Features of R&D systems and description of national system of science and technology in sub-Saharan Africa: lack of resources, interactivity issue, isolation of researchers	Classic characteristics of NIS (multiplicity of actors, political, institutional, cultural problems, interaction issues) and new propositions presented (inequality, development issues, biotechnology)	Learning at the heart of the analysis; need to focus the analysis on a national system of knowledge creation and learning based on the learning economy and theories of development	Technical change at the center of the analysis; explanations of the economic performance of nations; centrality of analysis on R&D activities	Interest in the technological development of nations; triple consideration of institutions, incentives, and capacities	Dynamic vision of innovation; focus on the role of institutions and organizations; research into micro-economic foundations of learning

	NIS *stricto sensu* [MAS 98]	Broad NIS without terminological adaptation [ARO 03, DUT 14]	Broad NIS with terminological adaptation [LUN 02, MUC 16]	National System of Technological Learning [VIO 03]	National System of Technological Capacities [LAL 00]	National System of Economic Learning [MAT 99]
Main proposals	Policy formulations: centrality on technological capabilities, establishing international projects, etc.	Clarification on the applicability of the concept in developing countries	National system of innovation and construction of competencies to highlight the richness of learning capabilities for the development of societies; double focus on innovation (ideas) and skills (non-codified knowledge)	Clear distinction between innovation and learning; typology based on elements of technological development: innovation, passive and active learning	Clear distinction between technological capacity and innovation; centrality around technological performance, and science and technology	Clear distinction between innovation systems and diffusion management; importance of the approach in institutional innovation for stimulating economic learning
Empirical applications	Sub-Saharan Africa, Maghreb	Latin America, China, NIC	Industrialized countries, sub-Saharan Africa	Brazil, South Korea	Emerging countries and Africa	Developing economies

Table 1.11. *Terminological variants of NIS*

1.3. Features of NIS in MINT

1.3.1. *Innovation, learning and classification*

Before looking at the features of NISs in MINT, we shall take a look at the classification of countries in the angle of innovation and learning economies [LUN 94]. We previously mentioned the distinction between developed, developing, emerging and less advanced countries, according to their wealth, in Table 1.5. Without falling into a very dichotomous description, we can simply refer to the lists of countries established by international institutions (World Bank, IMF), financial organizations (Goldman Sachs) or expert groups (Boston Consulting Group, Standards and Poor's), to identify the classification of these countries according to their GDP (developed/developing/emerging/less developed countries). In any case, the globalization of markets has failed to spread and diffuse all economic activities in a uniform manner. Economic activities are poorly distributed on a global scale. While industrialized countries benefit from *rich interactive spaces*, countries of the South have only *poorer interactive spaces* because of the scarcity of interactions between those with knowledge needs and those with learning capacities [ARO 03] (Box 1.6).

Neoclassical economists have mostly focused on allocation problems within a general equilibrium context. Individual agents, through their preferences and information including stocks of technical knowledge, had to make rational choices among the various alternatives proposed. Normative conclusions on the organization of the economic system were known from this perspective. However, this view, particularly criticized by the Aalborg School in its own foundations, could not be a goal of understanding current economic development phenomena. Indeed, if firms or nations increase their efforts on the allocation of existing resources (capital, labor) and if each separate unit creates the same product with the same technique, the latter become much less competitive because of the repercussions on demand.

It is therefore recognized that the success of innovation including tangible and intangible goods is more important than the prospect of resource allocation, especially in a context where the speed of change is

constantly accelerating. It is not so much about knowing how to distribute labor and capital resources than it is about creating and using different knowledge through learning processes.

Also, agents' learning capacities are more important than the information and specific knowledge that they have.

Learning capacities include the ability to do new things, cope with new situations and gain access to new information. In short, firms must constantly seek new knowledge to use in production, as new products or processes.

Box 1.6. *Learning capacities (innovation) versus resource allocation*

In the face of this unequal distribution of costs and benefits of economic development, there is a phenomenon of polarization in the distribution of wealth at the global level, the differential distribution of unequal income between countries, the growth of poverty and destitution in the world in developed and developing countries [CAS 99, p. 82]. Of course, this globalizing and inevitably reductive vision only makes it possible to present current trends. Thus, while it is clear that the development of new knowledge has accelerated the speed of change and created new technological gaps, its effects remain largely unequal across countries. It is easily proved by the recent growth of the MINT countries.

Nevertheless, since competitiveness is based on creativity, the ability to accumulate, renew and produce new knowledge, it is currently detrimental for a competitor to be unable to participate in different activities that demand knowledge [ARO 00] that involves strong participation in learning processes, broad skills and the ability to learn and apply knowledge. Furthermore, the learning economy creates the capacity to acquire and accumulate different forms of knowledge from codified knowledge to tacit knowledge. For this, the distribution of knowledge must allow the mobilization of various technological resources. It is through the combination of *opportunities* and *learning*

capabilities that a form of *polarization* will be exacerbated or diminished. In order to build learning capabilities, efforts must be made at the level of demand (new technologies, new skills, macroeconomic environment, technology policy) and supply (size of institutions, organizational and managerial skills, capacity to absorb technologies, access to external technical information) [LAL 92]. As for opportunities, they represent environments on which capabilities develop. These activities can be found in university research teams, organizations, the formation of *ad hoc* groups, the bringing together of hybrid groups within companies, through social and political actors (Box 1.7). Opportunities are also inherent in the importance and accession of international trade flows, for example, especially for trade in high-tech goods.

The diffusion process is linked to the assimilation of foreign knowledge by the actors of a country. Assimilation of this knowledge presupposes a certain "effort" that does not fully fall within the scope of the use of knowledge.

We cannot therefore refute the distinction made between *capabilities* in the sense of *distribution of knowledge* and *opportunities* in the sense of *activities that demand knowledge* [ARO 00]. The use of knowledge is a key aspect of innovation in developing countries [LAL 92, LUN 02].

However, its respective place in the learning economy seems to be largely neglected. In other words, NIS approaches are more concerned about the dissemination of knowledge by their actual distributions (in terms of creating organizations and learning institutions) than the use of knowledge by activities that demand knowledge.

Diffusion of knowledge relates to learning and/or technological capabilities. It makes it possible to transmit knowledge through multiple channels by technology transfer, from the "strictest" to the "widest", by building social capital. Learning capabilities are linked to the use of knowledge as much as innovation in developing economies is linked to the use and dissemination of foreign technologies.

But in terms of adapting the concept, activities requiring the use of knowledge quickly 'spread' through diffusion activities and prospects of knowledge distribution.

Also, analyses often focused on the following questions.

How to apply knowledge? Where to diffuse them? And this, without really knowing what actors (and spaces) use local knowledge (knowledge "users"). However, if places of diffusion are also places of application of knowledge (universities, when they diffuse knowledge and apply it *via* their R&D labs or firms, by learning process and staff career development), one can be completely distinct from the other or even not exist, as is often the case in less advanced economies where activities requiring knowledge application are rare.

In this case, when the question is actually dealt with, it is dealt with only in terms of a perspective that is restricted and limited in developed economies. The Aalborg School [LUN 02] deals with, for example, the demand for knowledge by analyzing the technique of *learning by interacting* and some actors, labor markets, education systems and human resources, considered potential users of knowledge.

Viotti [VIO 02], in his turn, concretizes it by the using R&D in the private and public sectors. However, in least developed countries, opportunities to apply knowledge must be thought of more broadly, with regard to the nature of an innovation.

Box 1.7. *Absorption of knowledge versus the use of knowledge in NIS works*

Two centers roughly emerged from this, with a kind of global control because of the United States' hegemony [HER 14]. The first, related to developed countries, gets its superiority from its capability to generate scientific and technical knowledge, diverted technoscience carriers of innovation and a social organization shaped together with scientific and technological development, and the second, related to developing and less advanced countries, has less scientific and technical knowledge but consumes more of the scientific and technical knowledge of the Northern Countries.

In developing and least developed countries, opportunities are fairly low and capabilities are often poorly built. Underutilization of capabilities is more damaging than capacity building, as the lack of opportunities tends to provoke a real capacity drain [ARO 06, p. 49]:

> "The learning divide can be more easily crossed at individual level: those who live in a country that as a whole is below the learning divide but have capacities that let them work above the line, find strong incentives to migrate and cross the divide. In this sense, the learning divide can be seen as a powerful brain-drain driver. The mismatch between capabilities and opportunities to apply them creatively is the source of great frustrations. These frustrations are not only related to the eventual inability to make a decent living from what people have learned after years of effort, but to the feeling of not being needed by a society that turns its back on what they have to offer while acquiring abroad the embodied or disembodied knowledge that these same people are able to provide".

We find the analysis of Sen [SEN 00] on development as freedom in which he shows the complementarity between capabilities related to the functions carried out (those that a person is currently able to do) and different alternatives that it possesses (actual opportunities).

The reasoning is similar here: the inadequacy of capabilities cannot be envisaged by building new learning capabilities (offering and distributing more or new possibilities in order to be competent) without the presence of opportunities (using newly established skills).

In developed countries, capabilities are more abundant, and there is a stronger R&D presence and wider opportunities, thanks to job markets being fonder of skills.

In emerging economies, where economic growth is visible despite signs of internal vulnerability, learning spaces are asymmetrical: capabilities are present [WOR 15a], but these are the opportunities that are less important with, among

other things, a fairly common underemployment [OEC 07], which is why there is a great heterogeneity of emerging countries.

Innovation and learning economy / Classification	Least developed countries (LDCs) and developing countries	Emerging countries	Developed economies
Interactive Spaces	Poor interactive learning spaces: few vertical and horizontal interrelationships	Asymmetric learning spaces, still underdeveloped	Rich learning spaces: innovation networks, links between production and university sector
Capabilities	Limited learning capabilities in R&D and engineering	Learning capabilities are present but not abundant	Learning capabilities are abundant and available
Opportunities	Limited learning opportunities: brain drain, little access to higher education; limited accession to international trade; long technology catch-up process	Limited learning opportunities: weak job markets that are informal and lack of highly skilled employees, etc.; accession to international trade; observable but heterogeneous technology catch-up process	Broader learning opportunities: job markets absorb skills (promoting employees, recruiting qualified employees, etc.)

Table 1.12. *Classification of countries in light of innovation and learning economy*

1.3.2. *NIS in MINT*

NISs were developed and built through their historical, social and cultural paths. In developing or emerging economies, the links they maintain with their key actors of innovation are often disjointed, weak or incomplete [CAS 17]. In this regard, ISs are built in an evolutionist perspective in which systems take different and very heterogeneous paths.

According to Dosi *et al.* [DOS 88], it is from a trajectory, represented as the activity of technological advancement along economic and technological constraints defined by the paradigm, that one can say that the innovation process is dynamic, sequential, cumulative and irreversible. Evolution is placed in a dynamic framework in which evolution's direction and intensity are key parameters and the notion of instantaneous equilibrium is not needed.

In the light of these main aspects, NISs (North and South) are built according to the following characteristics [MCK 97]:

– diversity and variety: diversity, in evolutionist approaches, is inherent in the creation of new things through learning processes [JOH 92];

– uncertainty: this is related to the cognitive capability limitation of actors, their differences and the heterogeneity of mobilized and developed knowledge. NISs evolve according to a selected path, while creating new combinations from their intrinsic dynamics;

– selectivity and historicity: change processes arise in a selected direction that is strengthened by feedback and adaptive responses. *Path dependency* or historicity[11] is the

11 According to Hoff and Stiglitz (2002), a society's history is linked to its technology, know-how and institutions. The impact of past events does not shrink with time. Sometimes, these events shape a specific stable state of the economy.

expression of a phenomenon in relation to the selectivity of the change. According to the latter, NIS will depend on the path to reach the final state;

– irreversibility: the innovation process is irreversible. This characteristic is found in NISs in the sense that it is impossible for the NISs to return to their initial state without modifying their external environment [NIO 92].

Altogether, the NIS never reaches an optimal stage and equilibrium because of learning processes (Box 1.8), which are subject to continual change, are not determined and dependent on development paths [EDQ 97]. It is established as a *complex dynamic system* [GU 99].

The fact that processes such as learning by doing, learning by using and learning by interacting are traditionally highlighted does not mean they are exhaustive.

Edquist [EDQ 01] thus opposed the organizational learning processes of individual learning processes, both being essential for the understanding of innovation phenomena.

Organizational learning processes are collective mechanisms controlled by the firms, and related to R&D and to techniques of imitation, use and interaction.

Individual learning processes (education, training) are directly controlled by individuals and affect human capital. These are real prerequisites of innovation processes, even if they do not concern it directly.

In this same perspective, Gregersen and Johnson [GRE 97] differentiate direct learning process from indirect learning processes.

Direct learning processes mainly aim at universities, research centers and R&D laboratories, and concern formal organizations.

Indirect learning processes affect the processes of learning by routine: learning by practice, use and interaction.

The common feature between these two processes is in their social and interactive nature.

To be more precise, Lindegaard [LIN 97] distinguishes direct learning processes from indirect processes in formal and informal institutions.

Thus, within the formal institutions, he cites incentives for academic research and various academic articles as direct learning, and work safety regulations and laws on democratic participation as indirect learning.

As informal institutions, he mentions banking sector norms on innovation project funding as direct learning, and norms and routines related to the balance between collective and individual research as indirect learning.

Finally, the overall learning process combines four types of knowledge, frequently cited by Lundvall and Johnson [LUN 94]: the know what or informational knowledge, the know why or understanding of social and natural phenomena (scientific knowledge), the know who or the social ability to cooperate and communicate and finally, the know how or the ability to do something at a practical level (experience).

The following taxonomy summarizes the different learning processes combined with various types of knowledge:

	Know-what	**Know-why**	**Know-how**	**Know-who**
Knowledge Type	Codified	Codified	Tacit	Tacit
Sources	Facts and information	Scientific principles and laws	Experience	Personal contacts in research groups and production networks
Transfer processes	Patents, formal business agreements	Journals, books	Training, learning by practicing and use, engineering	Networking, face-to-face contacts, joint research, exchange of personnel, professional association

Learning context	Digital libraries, formal institutions	Digital libraries, formal institutions	Workplace, research and training centres	Workplace, research and training centres

Table 1.13. *Processes, resources and types of knowledge (source: [OYE 04])*

Box 1.8. *Diversity of the learning process*

Chaminade and Vang [CHA 08] rightly opposed two types of ISs: emerging ISs and mature ISs.

In emerging ISs, cross-sectoral links are weak and the absence of interface units and universities specializing in labor supply is obvious. Forms of learning are limited because skills are weak and relationships lack confidence [LUN 92]. Forms of learning are weak because of research capabilities or a low level in universities and businesses. Companies and other elements of the system are not yet capable of producing radical innovations and do not accumulate enough knowledge to commit to different forms of interactive learning.

The emerging IS could, however, gradually become a mature IS. In mature ISs, interactions are carried out through market mechanisms, information links and other types of formal and informal networks. Businesses and other organizations of the system develop their capacity to absorb and participate in a continuous interactive learning with other companies, users, universities and other organizations of the system.

Table 1.14 shows the features between the two aforementioned forms.

Components	Mature IS	Emerging IS
Capability issues	Lack of technological capability and research and lack of interaction with the consumer Lack of major research facilities facilitating advanced search	Lack of engineering and design capabilities Lack of managerial skills Lack of learning organizations Lack of technical centers
Reticular problems	Lack of dense interfirm networks Weak industry–university networks	Weak links between local firms and multinational firms Weak links with consumers Need for links between universities and rural communities Low human capital between universities and industries Lack of bridging organizations
Institutional issues	Governance issues Intellectual property rights	Weak links between formal and informal institutions Social inclusion Corruption Intellectual property rights Low guarantees Weak innovation-friendly regulation

Table 1.14. *Mature IS versus emerging IS (source: [CHA 08])*

It is in the interest of the IS to move from the "emerging" category to the "mature" category. While developing countries are more in the "emerging" category, developed countries have "mature" ISs.

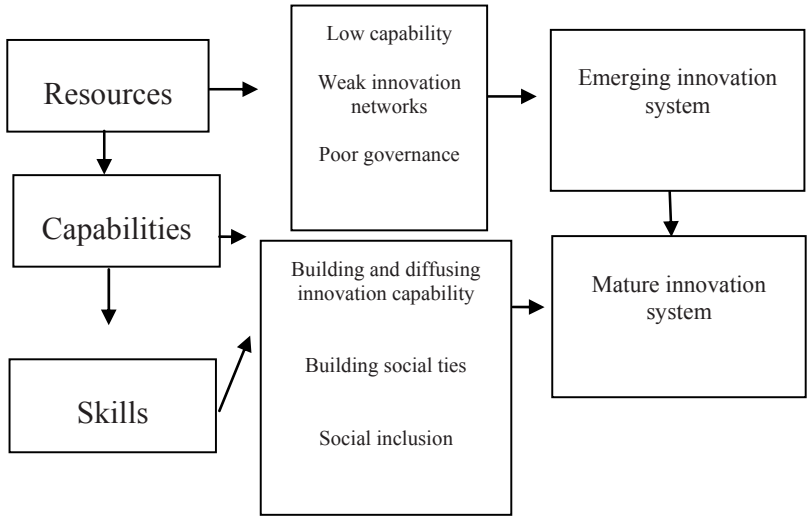


Figure 1.3. *From resources to skills: from emerging IS to mature IS*

Therefore, under which category do emerging countries like the MINT go? The issue is therefore to know whether their growth rate impacts their innovation ties or whether, on the contrary, their exponential growth has but a small tie with their systemic innovation.

We have defined emerging countries using a certain number of improved aggregates (including GDP), but does this mean the same thing in building/developing their NIS? That is what we are going to check in the second part, while conceptualizing our problem using Figure 1.3. To complete our empirical approach, we will use four indicators presented as a source of technological learning: education and training, technology acquisition, resources and outcomes in terms of technological effort. To this, we will add the intensity of links and governance in terms of S&T, which seem to be of prime importance in the analysis of an NIS.