National Innovation Systems in Low-Income and Middle-Income Countries: Re-evaluation of Indicators and Lessons for a Learning Economy in Senegal

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Abstract

The National Innovation System (NIS) approach exists today in multiple terminologies, through a variety of conceptualizations all seeking to provide real means of action to public decision-makers on the issue of innovation, knowledge and economic development. This approach was originally defined by and for high-income countries and not for low- and middle-income countries. Based on the classification of the countries of the World Bank on the Gross National Income of the countries studied, our article proposes to focus on the relevant indicators, not predefined upstream, in order to measure and evaluate the systemic innovation of the low- and middle-income countries, from a learning economy perspective. To answer this, we propose a qualitative model that we validate in the case of Senegal. A low-income economy, it draws most of its efforts not in terms of S&T but more broadly in its learning policy, its reforms on higher education or proposals on entrepreneurship. These efforts are commendable in an economy where macroeconomic conditions are holding back its growth. The originality of our research relates to the implementation of these indicators and the lessons it brings to Senegal on the richness of the exploitation of capacities and skills as a vector of a learning economy.

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After more than 30 years' analysis on National Innovation Systems (NIS), which mainly originated with Lundvall (1992), Freeman (1987) or Nelson (1993) on the issue of developed countries, it remains important today to pay special attention to its formalisation in low- and middle-income countries. The classification of countries according to their income was established by the World Bank according to the measure of Gross National Income (GNI). If GNI is below 1025 dollars per

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inhabitant, the country is classified as low, and between 1026 and 4035 dollars, it becomes middle in the lower range. Most sub-Saharan economies are thus judged to be low income, and some Asian countries, such as Cambodia or Mongolia, are classified as middle-income. The interest in this category of country is linked to two reasons: the NIS approach was created for and by developed countries (Japan and Scandinavian countries), suggesting the establishment of predefined criteria by and for developed countries. In addition, innovation and the definition of suitable policies can appear not to be a priority, in view of fundamental problems like poverty or health within these economies (Johnson et al., 2003). Accordingly, studies on low- or middle-income NIS were only developed tentatively from the 2000s, when the themes of innovation and learning combined with problems of (under)development. In 2002, out of 750 innovation systems analysed, only 92 were realised in low- or middle-income countries (Xu & Carlsson, 2005).

Both a conceptual approach and a tool to formalise scientific and technological policies (Edquist, 1997), today, the NIS exists under many different terminologies, through a variety of conceptualisations, all seeking to provide real scope for action to public decision-makers on the issue of innovation and technological development. The question posed here is therefore to know what the relevant indicators are, not predefined in advance, in order to measure and assess systemic innovation in these countries in the light of a learning economy (Lundvall, 1992). But this question is ambitious because to consider NIS in this category of country is to consider the great heterogeneity of their trajectories of development: in fact, there are many ways of innovating, learning, resolving problems, and not one single NIS model (Chaminade et al., 2018). Consequently, to respond to this, we propose a qualitative model, more suitable to interpret problems of capacities and opportunities for absorbing knowledge of Senegal. The NIS approach should be formalised on criteria suitable for the land that they exploit, especially as theoretical developments proliferate on the new open, sustainable, green and inclusive NIS, and current indicators are not always appropriate or updated.

From an empirical point of view, we chose the case of Senegal for several reasons: it is a poor country, whose fundamental and structural problems are not geared towards innovation. In addition, studies relating to innovation in this country are more oriented towards agricultural innovation (Dugué et al., 2018). A case study will thus shed light on the questions of innovation policy, and their realization. Secondary data collected through official documents and government sources will be used in the case study. These data will be qualitatively assessed in our second part.

Our results in Senegal show that these indicators do not appear as a real goal but as a means of improving the growth and dissemination of knowledge in these countries. We are therefore interested in the means to be provided to innovate, and not in the technological objectives to be achieved. Thus, Senegal is making a certain number of efforts in this direction, without however seeing the S&T indicators progress strongly. These efforts are local, sectoral and to be interpreted in a broad sense. Our paper is structured as follows: we first establish the current characteristics of NISs in low-income and middle-income countries under the learning economy milestone (§1) before proposing relevant indicators and appropriate in the context of learning economy (§2) and apply them in a low-income economy: the Senegal (§3).

NISs in Low- and Middle-Income Countries: Characteristics and Current Challenges for a Learning Economy

Common and Specific Characteristics

If NIS are the subject of a scientific consensus concerning their territorial delimitation, conceptualisation of the latter in low- and middle-income countries is far from being unanimous, despite a certain number of consistent characteristics. Nevertheless, these innovation systems are “open” (Bellon & Niosi, 1994) and “globalised” (Binz & Truffer, 2017), and the role of multinationals and their activities, through which they can exchange knowledge and technologies through partnerships, remains essential (Watkins et al., 2015). There are two opposing approaches in the definition of systemic innovation: a narrow approach linked to R&D activities and to science and technology (Nelson, 1993), and a broader approach linked to learning processes (Lundvall, 1992). Obviously, it is the “broad” approach (Table 1) that merits most attention in low- and middle-income countries. This is because it best corresponds to the definition of their innovation model (Casadella et al., 2015).

However, the NIS has characteristics which are similar to all forms of economies examined (Edquist, 1997):

- It places innovation and learning processes at the centre of the approach
- It adopts a holistic and interdisciplinary approach
- It uses a historical perspective on the approach and considers innovation processes as evolutionary
- It underlines the differences between systems and rejects the notion of *optimum*
- It emphasises the interdependence between systemic components defined as genuine actors
- It includes the products and processes of innovation, just like their development and diffusion
- It emphasises the central role of institutions as rules of the game
- It highlights its diffuse nature
- It represents a conceptual structure instead of a real formal theory

We also find characteristics that are more specific and adapted to low- and middle-income countries (Table 2).

To take each point, the NIS of these countries is identified more from their conditions of emergence and development. The term construction or emergence (Lundvall et al., 2002; Tigabu et al., 2015) is mentioned as a substitute for their reproduction, inherent in high-income countries. In low- or middle-income countries, these NIS are constructed or deconstructed because of the disjointed nature of their links and their difficulties in getting out of their technological dependence (Gaillard & Bouabib, 2017).

Then, in these countries, innovation, as the capacity to create new products and processes, remains less important than the capacity to use and adapt existing

Table 1 Interaction between formal and informal elements of the innovation system

	Narrow	Broad
Formal	Formal organisations, institutions and networks linked to science and technology	Organisations promoting innovation in general, formal institutions and networks
Informal	Informal networks and institutions linked to science and technology	Informal institutions influencing innovation and informal networks (such as historical and cultural values)

Source: Adapted from Schoser (1999)

Table 2 The characteristics of NIS in low- and middle-income countries

	Characteristics
A posteriori nature of the NIS (Lundvall et al., 2002)	Conditions for the emergence of NIS in low- and middle-income countries
Technological capacities (Lall, 1992)	Process of technological absorption and diffusion Incremental innovation
Heterogeneity of trajectories of development (Edquist, 2001)	Study of the different stages of development, strategies for those lagging behind to catch up
Innovation processes in low and medium technologies (Johnson & Lundvall, 2003; Muchie et al., 2003)	Broad representation of innovation through low and medium technologies
Innovation and social entrepreneurship (Rao-Nicholson et al., 2017)	Importance of social innovation
Position of social capital (Arocena & Sutz, 2003)	Importance of trust and social links
Position of informality and indigenous knowledge (Jauhiainen & Hooli, 2017)	Importance of informal indigenous technologies
Global technological environment (Binz & Truffer, 2017)	Consideration of the local and international context
Complex financing of innovations	Importance of private institutions and microfinance

technologies at competitive levels of costs and quality (Lall & Pietrobelli, 2002). Innovation is no longer at the frontier of technology but includes strategies of catching up, implemented by those lagging behind.

We also note the heterogeneity of their trajectories of development. These tend to emphasise the many differences between national systems (coming from their history, religion, class, etc.) and to enhance the different stages of development they attain (Edquist, 2001). Another characteristic: the NIS approach in developing countries enhances innovation processes in low and medium technologies without being limited to high-tech sectors (Johnson & Lundvall, 2003). While innovations in high-tech sectors are sophisticated and based on science and radical innovation, the NIS of these economies is the reflection of conventional perspectives of learning within small traditional structures. Another point relates to the importance of innovation and social entrepreneurship in the NIS approach and relates to the creation of social values through the use of innovative resources (Rao-Nicholson et al., 2017). Social innovations follow a mechanism of the reinforcement of institutional arrangements by accumulating public and private interests.

There is another element that is vital for understanding these NIS: the formation of social capital. The construction of innovation results from the institutional framework, which is strongly influenced by society itself. Another element is the position of indigenous knowledge and informal technologies (Jauhiainen & Hooli, 2017). Indigenous knowledge, linked to local traditions, was in fact taken into account in innovation policies in the countries of sub-Saharan Africa (Nfila & Jain, 2011). Then, the global environment is particularly important, not only to take into account the degree of intensity between national and international (Binz & Truffer, 2017),

but also to measure the impact of a global crisis on one NIS in particular (Filippetti & Archibugi, 2011).

Finally, financing is one of the main problems encountered in infrastructure development and the promotion of industrialisation and agriculture in low- and middle-income countries. Generally, the almost generalised failure of the public banks at the beginning of the 1980s and the establishment of structural adjustment programmes in the 1990s significantly reduced the share of these states in granting of credits. With the gradual disengagement of states, the banks and microfinance institutions play a more important role in innovation transfer (Traore et al., 2020). New initiatives and rules developed by these financial institutions helped to diversify the offer of financial services to producers beyond traditional credit mechanisms (Kloeppinger-Todd & Sharma, 2010).

Current Issues Around Inclusiveness

Currently, the NIS is no longer only perceived as an instrument relating to technological performances, but as an instrument linked to the understanding of economic development (Lundvall et al., 2002). Two themes have recently entered the literature on current innovation systems: that of inclusive innovation and green innovation.

Inclusive innovation shows how the development of technologies, coupled with social policies aimed at reducing inequalities, are important levers in developing economies (Lundvall & Lema, 2014). The inclusion can be “passive” or “active”, depending on the degree to which individuals and communities can play an “active” role in economic development. Passive inclusion represents the reduction in income inequalities, creating employment and incentives to increase the income of the poor. Active inclusion considers that segments excluded from society should participate directly, through their rights and contributions, to the process of development and innovation (Heeks et al., 2014). The intended goal is wellbeing, improving the quality of life and reducing poverty. These innovations can, in fact, also be considered as a form of social innovation, defined as a product, a process or a technology, or even as an idea, a legislative reference, a social movement, a public intervention or the combination of some of these (Phils et al., 2008). Inclusive innovation has an essential place in NIS works to understand how technological and non-technological innovations, realised by the poorest or by all the other actors in society, have been used by all organisations, communities and civil societies.

Still in a perspective of new approaches, sustainable development is an important theme, which has not been heard about enough in NIS works (Johnson et al., 2017). A plethora of concepts has emerged from sustainable innovations: environmental innovations, low carbon innovations, eco-innovation and socio-ecological innovations (Franceschini et al., 2016). All these definitions have in common the fact of finding technological, social or institutional solutions to improve the environmental impact on human activity (Chaminade et al., 2018). Superimposed on the NIS approach, a system of sustainable innovation is made up of social, human and natural elements, as well as relations which interact in the production, diffusion and use of new and economically profitable knowledge (Segura-Bonilla, 2003).

Consequently, we can envisage an NIS for sustainable development or sustainable innovation as a new twenty-first century opportunity (Segura-Bonilla, 2003).

The Place of the Learning Economy in NIS Literature

Learning theories emanate from the Scandinavian School (Lundvall, 1992).

They lie at the crossroads of evolutionary and institutionalist theories and represent the central core of the NIS. Two principles highlight the role of learning and knowledge within the approach:

The first principle lies in its positioning: the centrality of learning in the NIS theories implies, on the one hand, that the NIS efficiency is a main factor of growth and economic development. This finding tends to mark the opposition with classical economic theories in which the endowments of capital and labour are the keys to economic development. This approach also rejects the position that people who learn do not innovate. On the other hand, it implies that the capacity of a nation to continuously generate new ideas and competencies and thus to accumulate new knowledge is the driving idea of the long-term economic prospects of nations.

At the heart of NIS, the learning processes are in permanent connection with the routine activities of production and distribution. The speed and form of learning are essential factors in the competitiveness and creativity of nations. They have multiple aspects, the main ones being learning by doing (Arrow), learning by using (Rosenberg), learning by interacting (Lundvall) but also learning through research, exploration or re-learning processes (Johnson, 1992).

The second principle lies in the enhancement of the interactive and institutional framework within the learning process. This perspective introduces the idea of the interactivity mechanism rejecting the hypothesis of unidirectional sequentiality of learning processes. Learning mechanisms are the result of connectivity between those who benefit from new ideas and seek to expand their applicability and those who use them and demonstrate continuously revised needs. On the other hand, learning, as a cumulative process, is incorporated into the institutional dynamics of the NIS. Learning does not take place only by individuals within firms but also within public and private organizations and institutions. If institutions regulate and shape learning channels, they themselves must go through a learning process called institutional learning (Johnson, 1992). According to him, it is about the effective capacity of national economies to face their problems through their capacity to learn, to learn to adapt and possibly to change their institutional structures.

However, this theoretical framework will remain restrictive in its initial conception. In fact, in the first work of Lundvall (1992), the authors limit themselves loosely to “classic” learning processes (learning by doing, using, interacting) while remaining imprecise as to who learns what, in what way and how learning remains linked to innovation processes. Gradually, education, training or individual learning (Edquist, 2001) will enter as key components of recent NIS literature (Lundvall & Christensen, 1999). The same will be true for the recognition of individual learning within organizations.

The role of learning in the NIS approach takes on a new aspect in that it makes much less reference to restrictive learning processes than to all the learning capacities of firms, organizations and regions (Lundvall et al., 2002). In other words, it is more generally an interest in what Johnson et al. calls “the learning capacities as a whole” (Johnson et al., 2003), namely the set of learning processes, collective and individual, direct and indirect and the diversity of forms of learning. There are therefore a multitude of paths through which individuals, firms and nations are likely to learn. The learning economy is pervasive, diverse and permeates all parts of the economy. Learning takes place at all levels: technological, organizational, individual and societal. All of these combinations are essential for national capacity building because they determine whether companies, industry groups and states succeed or fail in their growth strategies.

The contextual framework of the learning economy allows NISs to glimpse their full learning perspectives and therefore understand, in the face of the accelerating speed of change, how some NISs respond better than others to the process of change.

Relevant Indicators for NIS in Low- and Middle-Income Countries

The assessment on NIS for low- and middle-income countries encourages us in this regard to select two important elements:

- Their specificity despite their very great heterogeneity,
- Their objective of dissemination and use of knowledge

Consequently, we will adapt these elements around the construction of relevant indicators.

The Failure of Quantitative Instruments

On the issue of low- and middle-income countries, two forms of studies are envisaged: descriptive studies and formalised studies (Balzat, 2002). But the latter are not always relevant in current inclusive logics.

Two forms of studies are most often represented. These are descriptive and formalised studies. They help to achieve purely political strategies and/or aim to enhance the conceptual structure of the approach (Balzat, 2002). When they assume a political interest, they are generally carried out by the European Commission, the OECD, UNCTAD or the World Bank; their objective is to develop indicators and a methodology to compare national scientific policies. When they do not have a political purpose, they serve to understand the phenomena of systemic innovation at national level. Amongst descriptive models (Chang & Chen, 2004), Liu and White (2001) identify five activities relating to the innovation process: research, production, users (end use), interactions and education. Their analysis is based on the distribution of activities in innovation processes, mechanisms of control and coordination and information flows. They apply this method to analyse the Chinese NIS

through an inter-temporal comparison of the different stages of development. Institutional and organisational differences are thus obtained between the NIS of Communist China and that of democratic China.

Parallel to the descriptive models, formalised models emerged to quantify more “formally” the innovative performance of nations. Some authors seek to construct instruments to track NIS (Godinho et al., 2003). For example, Furman et al. (2002) have proposed the concept of “national innovative capacity” as the capacity of a country to produce and market a technology flow in relation to the national infrastructure, the environment of industrial groups and the nature of links between the two. Each element, infrastructure, environment of clusters and links is measured by variables forming a specific model of decline. In a similar vein, Arcelus and Nasierowsky (1999) have identified national technological capacities on the basis of a system of structural equations based on inputs, outputs and moderators. Their analysis led to a classification of two groups of countries, technological leaders and other emerging countries, the technological progress of which is based on importing innovations developed abroad. After carrying out initial empirical tests, more recently, they have devised a model with two inputs, two moderators and three outputs. The efficiency of the NIS is based on R&D, as well as on its productivity. The overall idea is to perceive the NIS as an isolated sector of the entire economy.

The most commonly cited index used to measure innovation is the Composite Innovation Index, created by WIPO (Wipo, 2019). The 80 indicators proposed range from instruments of conventional measurement, such as investment in R&D, international patent requests and requests for the international registration of brands, to new indicators, such as, in particular, the creation of mobile applications and the export of high technology products. The Potential Innovation Index (PII) is another index used to diagnose the capacity to innovate according to 18 internal activities (Enjolras et al., 2018). However, this index does not take account of the environment of the firm.

More specifically, the indicators defined in the NIS approach are very heterogeneous. Currently, three types of these can be distinguished (Lizuka & Hollanders, 2017):

- Science and Technology indicators (publications, patents, R&D resources, R&D personnel)
- Indicators from surveys on innovation, collected from firms, and linked to the results of innovation (% of sales linked to new products, introduction of new products and processes), expenditure on innovation (patents, licences, ideas on personnel training, market analysis) and information on what precedes innovation (sources of knowledge, obstacles to innovate)
- Composite indicators, as we have cited above

Many low- and middle-income countries have used these innovation indicators. Except that these are not always suitable, particularly on adaptation to their needs (Tijssen & Hollanders, 2006). In addition, these indicators were created by simplifying complex phenomena, and by only emphasising some magnified aspects that are not very representative (Esperand & Sauder, 2012). Furthermore, these indicators

were created on the basis of research activity, as conceptualised in high-income countries. And yet, as seen recently, the NIS of low- and middle-income countries is constructed more on a logic of learning (formal and informal) than on R&D, strictly speaking. Finally, the indicators influencing S&T have had a very limited effect, particularly because these policies were not aligned with social policies and therefore lacked coordination and a horizontal approach (Lemarchand, 2010).

The Relevance of Qualitative Instruments and the Proposed Model

The NIS of low- and middle-income countries is indisputably based on qualitative elements (interpersonal, normative, informal, constructed *ex-ante*). But we cannot dismiss the difficulties in quantifying these qualitative aspects. We must, then, absolutely combine macro and micro indicators, as only one micro type *bottom-up* approach is currently discussed in the literature (Aguirre-Bastos & Weber, 2017). It should be supplemented by a *top-down* approach, of the macro kind, leading us to consider innovation policies to strengthen the capacities of local communities and disadvantaged areas.

Here, the methodology that we have chosen can be found in constructing *development blocs* (Dahmen, 1989). These blocs are identified as qualitative aspects of innovation. They are based on diversified channels of learning and refer to interdependent and interconnected factors associated with technological development. These *blocs* analyse sequences of complementarities which create the dynamic of the system and produce a potential for development. They thus represent a relevant conceptual structure to analyse the transformations that occur within the NIS.

The proposed model is presented in six *development blocs* (or subsystems). If we had to classify these subsystems, in line with the work of Arcelus and Nasierowsky (1999), we would obtain two *inputs*, two *moderators* and two *outputs*. The *inputs* represent learning capacities; *moderators*, the elements of the national structure with an impact on *inputs/outputs* and, finally, the *outputs* integrated into the “results” from learning efforts.

Among the *inputs*:

- Learning capacities
- Learning culture.

Among the *moderators*:

- Learning demands
- Learning links.

And finally, among the *outputs*:

- Local readaptation of knowledge;
- Improvement in the quality of life.

Learning Capacities

The learning effort represents categories of firms which have spent a sum of money, even minimal, on research activities or activities which aim to produce innovations (Naclerio, 2004). Some firms can thus innovate without making any particular efforts (the case of reactive firms which respond to a particular economic situation and stable technologies), innovate by making real efforts (the case of proactive firms or radical innovations) or do not innovate at all. The implicit effort corresponds to the development of new technological knowledge, to a change in communication codes, or interactions between producers and users. Consequently, innovative firms making technological efforts are combined with active learning systems and those which do not make efforts with passive learning systems (Viotti, 2002).

Learning capacity presents the potential improvement in access to knowledge. This improves the different possibilities for access to knowledge by strengthening individual and collective skills. Thus, the provision of knowledge in relation to activities to resolve problems is a first necessary condition for our model.

Learning efforts correspond to the five following indicators:

- Access to learning institutions
- Number of researchers and scientific diaspora
- Level of general qualification
- Scientific research groups
- Situation of firms and learner organisations

Access to institutions is measured by the number of technological institutions, as well as by all the non-technological interfaces (training institutions, chambers of commerce and industry etc.). Access to knowledge institutions helps to measure the level of the democratisation of knowledge.

The existence of a scientific diaspora means that foreign researchers are considered to be an important part of the national research community. The diaspora is a real force for learning, the dynamism of which varies depending on the degree of engagement of public policies. But measuring the number of researchers is not straightforward in view of the many scientific migrations.

Another indicator can be found in the level of qualification of the population. This identifies the level attained by the population through the education rate and literacy of young schoolchildren.

Scientific research groups learn through units (formal) of research and numbers of research projects. This is where we find evidence of the importance of the university activities described earlier (Albuquerque et al., 2015).

Finally, the number of SMEs founded on knowledge is a major asset as a driver of economic growth. In low- and middle-income countries, these firms play a role of technological tailors capable of finding tailored solutions by using scientific instruments. Without the presence of these firms, capable of establishing relations with the users of knowledge, speaking the same language and developing the same codes, firms will find it difficult to develop new technologies. These include, in particular, firms which maintain solid links with knowledge networks.

Culture of Learning

The culture of learning (Johnson & Lundvall, 2003), representing the diversity of sources of learning, is a qualitative variable that is particularly difficult to quantify because of these tacit and informal aspects. The issue raised here is to define the frequency of firms' learning activities and assess their composite nature.

Is learning (of a product or a process) a daily activity of firms? How are learning activities organised by actors in an organisation? What are the different learning activities deployed by firms?

Low-income economies are often based on informal learning, and knowledge is generally a form of secret transmitted to the apprentice from descendant to descendant (Oyelaran-Oyeyinka, 2004). By transforming codified foreign knowledge into local use, only a small proportion is transferred through formal methods. What remains requires a long heuristic process of imitation, reverse engineering and learning techniques. This non-formal knowledge has direct repercussions for firm performance (Ducatel, 1988). As literature on NIS often favour formal institutions, we must look at non-formal knowledge, essential for the process of absorption of technologies.

The following indicators will be established on a microeconomic scale:

- Profile of firm learning activities
- Frequency of firm learning activities

The first indicator proposes to target firm learning channels in order to understand their main forms. The purpose is, if necessary, to draw out new learning techniques and, through this, to broaden the NIS approach.

As for the frequency of learning activities, this will help us to understand if firms consider learning to be an essential right or if the problems of internal or external conflicts restrict their potential applications.

Demand for Learning

The deployment of learning capacities and the acquisition of technological capacities are linked to opportunities to apply knowledge in the face of problems encountered (Arocena & Sutz, 1999). In other words, improving learning cannot be explained as a simple phenomenon based on the supply and demand of knowledge but on supply and demand in relation to the existing institutional framework. What clearly appears in the initial approaches of Von Hippel (1988) seems to be less so in works on NIS, which tend to underestimate the diversity of knowledge users.

This variable responds to the questions: Who uses? How to use knowledge? Where to use knowledge? With this in mind, the indicators proposed will be the following:

- Demand for knowledge from the public sphere
- Demand for knowledge from the private sphere

Public demand for knowledge is crucial when we acknowledge that privatisation processes come from political choices.

In order to establish a consistent measure for this moderator, we will consider satisfaction of the state's internal demand (political strategies, recruitment of researchers, number of projects established, public financing of innovations, regulatory system) and the existence of public demand concerning local needs. From that, we can know where and how the state uses existing knowledge. This public demand is significant. To cite just one example on public financing, public credit favoured agricultural intensification in cash crop areas in sub-Saharan Africa (Témé, 2016). It also helped to reindustrialise some sectors by setting up innovative project or relevant fiscal measures. But the limits of public demand have been revealed to be major with the gradual disengagement of states in a certain number of low- and middle-income countries. Private demand therefore appears to be legitimate and recognises the importance of users of knowledge and the influence that they exert on local institutions.

This demand more particularly concerns workers and consumers through private organisations and institutions. Banks and microfinance institutions (MFIs) therefore played a key role in the transfer of innovations, particularly in the agricultural sector. These new actors define their financing policy and establish risk financing strategies with actors specialising in financing innovation. These financial intermediaries are a major category of actors present in national innovation systems (Cooke, 2001).

Learning Links

The effectiveness of learning processes depends on the nature of interaction, the proximity of which is not territorial but behavioural. The interactive dimension of learning, learning-by-interacting (inter-firms and intra-firms), is the foundation of diffusion processes and the use of knowledge. According to Oyelaran-Oyeyinka (2004), a systemic positive dynamic is reproduced at a national level when the following are established: (i) a variety of links requiring offerors, producers and service providers; (ii) a propensity to cooperation and collaboration; (iii) a large number of actors diffusing information and the knowledge needed to produce goods and services; (iv) a propensity to encourage private initiatives by public demand and (v) strong local–global formal and/or informal networking.

In this case, the systemic aspect will include the following points:

- Horizontal collaborations
- Subcontracting
- Links developed with the agricultural, industrial and service sector
- Cooperation with suppliers
- Collaborations with universities (and other learning interfaces)
- Links developed with foreign firms

Local Readaptation of Knowledge

Readaptation is understood to be the result of the efforts (capacities) and demand of learning. This is about finding the trajectories of use of local knowledge. But how can we quantify the degree of readaptation of knowledge or the externalisation of knowledge?

In most studies, the final result, the output, is integrated into the end product or the new process. The defined variable is often an improvement in the product, the process, the organisation of production, new equipment, new products and new processes. Having said this, in low- and middle-income countries, the sought-after aim is not *stricto sensu* innovation but a number of objectives to be achieved (improvement in learning) regarding exogenous knowledge (scientific and general) and traditional knowledge (inherited from a culture of reference). Indigenous systems of knowledge can, for example, represent these objectives and appear as real engagements between a present and a future situation (Bertelsen & Muller, 2003). For example, setting up projects also remains an output relating to building competences. One project shows how knowledge can be diffused and used with a view to an active reappropriation of knowledge (Davies & Hobday, 2005).

The proposed sub-indicator is, then, the following:

- Objectives achieved by the firm, helping to improve knowledge
- Objectives achieved by public decision-makers to improve knowledge

If, for example, the firm has recruited qualified personnel, commits to training plans and the personnel emerge from this with some certification, then we can talk about a real result. Similarly, if public decision-makers encourage real social policies in favour of learning, we can also talk of a result.

Inclusive Innovation and Capabilities

As underlined, works on NIS are currently proposing the variable development as a tool of the NIS approach. The aspects studied take very different forms as long as this is in line to measure the quality of life of individuals through innovation and learning. But if the theoretical justification is indeed real, empirical studies still remain insufficient. Because we cannot reduce human beings to means of production and these are also a real purpose (Sen, 2000), the indicators in question should measure the level of social or political development of individuals.

More specifically, this concerns presenting the preceding output with the following sub-indicators:

- Inclusive innovation and social development
- Inclusive innovation and political development

These sub-indicators allow us to pose the following questions: has carrying out company projects or the development of indigenous knowledge systems had repercussions for the fertility rate? Infant mortality? Evaluation of the role of women?

Or even the quality of public debate? The responses provided vary according to the previous output (variable 5). They can certainly be limited to a short-term social development (example of the role of women in a company project) or to any political development (example of the creation of a home-owners association faced with a contentious project), with the main idea being to integrate the impact of social opportunities in this model.

By way of a recap, the table below provides the summary of the proposed model. Undeniably, var. 1 will come from secondary data, but var. 2 to 6 from field surveys, both through semi-structured interviews, and observations from visits. Data from secondary sources (var. 1) should be input to be able to triangulate the information with its context. As the literature on NIS tends to be static and present very simplified general descriptive studies (Xu & Carlsson, 2005), evidently, it is the evolution of the whole system that will interest us and not some comparative approach (Table 3).

The Study Case in Senegal

This case study focuses on secondary data collected at the start of 2021. This study focuses on the qualitative variables proposed to define a national innovation system. Some variables have less value than others insofar as they must be accompanied by microeconomic studies (especially for the culture of learning). Before returning to each variable, it is necessary to look at the overall macroeconomic context of the country.

Macroeconomic Conditions

With a population of 15.85 million in 2018, with an average GDP per capita of \$1521.95 (World Bank, 2018), Senegal is classified by the United Nations (UN) as a least developed country (LDC). It nevertheless displays its political ambition to the status of emerging countries by playing a leading role in regional economies within the West African Economic and Monetary Union (WAEMU). An illustrative example of democracy (although the current situation of violence calls into question the principle of democracy), benefiting from the most important development aid as well as monetary agreements with France within the franc zone (allowing it to avoid any problem of currency availability and any internal monetary slippage), Senegal has inevitably made a number of mistakes in its economic policy, rating it as a least developed country against several UN criteria.

The Senegalese economy has undergone four major phases of development since independence: (i) the period 1960–1983 marked by irregular growth; (ii) the period 1983–1994 corresponding to the exclusive use of internal adjustment, characterized by a lack of investment and a loss of growth and competitiveness; (iii) the post-devaluation decade (1995–2005) marked by further reforms and accelerated growth; and (iv) the post-2005 period characterized by a decline in economic growth. From 2006 onwards, a clear inflection of growth was noted, in connection with factors

Table 3 Presentation of the NIS model in low- and middle-income countries

Variables subvariables	Learning capacities	Culture of learning	Demand for learning	Learning links	Local readaptation of knowledge	Inclusive innovation
1	Access to learning institutions	Profile of firm learning activities	Demand for knowledge from the public sphere	Horizontal collaborations	Objectives achieved by the firm in terms of improvement in knowledge	Innovation and social development
2	Number of researchers and scientific diaspora	Frequency of firm learning activities	Demand for knowledge from the private sphere	Subcontracting	Objectives achieved by the public sector in terms of improvement in knowledge	Innovation and political development
3	General qualification level			Links developed with the industrial sector and services		
4	Scientific research groups			Collaborations with providers		
5	Number and identification of learner organisations			Collaborations with universities and other learning interfaces		
6				Collaborations with foreign firms		

of fragility and volatility. Indeed, the global economy has experienced a series of shocks of a diverse nature: the food crisis and soaring commodity prices in 2007, soaring oil prices in 2008, the economic and financial crisis resulting from the “sub-prime mortgage” in 2007/2008, the 2011 earthquake in Japan, the socio-political unrest in the Maghreb and the Middle East in 2011, the sovereign debt crisis in Europe and the USA. In the sub region, the political and security crises also affected the Senegalese economy. Since early 2020, the coronavirus pandemic (COVID-19) has significantly changed the country’s economic outlook. In 2020, growth slowed sharply, falling to an estimated level of 1.3%, with services (such as tourism and transport) and exports being particularly affected.

On the commercial side, Senegal trade balance 2019 is \$ – 3.52 billions, a 4.52% increase from 2018. Developments in exports are mainly due to increased sales of peanuts and cotton, while imports are driven by a substantial increase in capital goods and intermediates.

The unemployment rate represents 48% of the total population. According to the international labour organization, it ranks the country among the 3 most affected countries in the world.¹ Young people play an important role in the overall workforce of the unemployed. But since the individual who does not have his own resources can survive to create his own job on the industrial sector, unemployment would be reserved for privileged groups, and the real tensions would tend to be at the level of underemployment. The informal sector thus emerges as the only alternative for large segments of the population. However, it is characterized by low wages, poor working conditions and a lack of social protection.

1. Learning Capacities

We will present learning capacities through the institutional context, learning policies, R&D policies and regional, sectoral S&T policies.

Institutional Landscape

The institutional landscape is relatively dense. At the institutional level, the lead ministry in charge of research Ministry of Higher Education and Research. In the field of agricultural research, the Senegalese Institute of Agricultural Research (ISRA) is under the Ministry of Agriculture and Rural Equipment. The Institute of Food Technology (ITA) is under the supervision of the Ministry of Mines, Industry and Processing of agricultural products and small- and medium-sized enterprises (SMEs). In Senegal, the governance of innovation policy is defined by the Ministry of Higher Education of Technological Research. It is coordinated by a National Agency for Applied Scientific Research. However, the administrative and technical supervision of different ministries and the lack of a single steering of research and innovation result in a dispersion and fragmentation of research through a multiplication and

¹ <https://worldpopulationreview.com/country-rankings/unemployment-by-country>

Table 4 Institutional S&T supports in Senegal

Senegal—2021
Tertiary Education Public universities: UCAD: Cheikh-Anta-Diop University UGB: Gaston-Berger University, in Saint-Louis UADB: Alioune Diop University of Bambey UT: University of Thiès UASZ: Assane Seck Ziguinchor University UVS: Virtual University of Senegal USSEIN: University of Sine Saloum El Hadji Ibrahima Niass UAM: Amadou Mahtar Mbow University Private universities: Amadou Hampaté Bâ University Dakar-Bourguiba University Sahel University Catholic University of West Africa Kocc Barma University El Hadji Ibrahima Niass University Dakar Institute of Technology Public research centers Senegalese Agricultural Research Institute Food Technology Institute Renewable Energy Study and Research Center National Institute of Pedology Ecological Monitoring Center Sahel ecotoxicology research center Laboratories of the Plant Protection Directorate National Agency for Applied Scientific Research Senegalese Agency for Technological Innovation Foreign, regional and international research centers (BRED, CRDI, CRAT, IRD) Private Sector Pasteur Foundation Prometra Manobi Ceres locutox Sodefitex
Sources: Authors

superposition of priorities, a weakness and fragmentation of the sources of Financing and a lack of mechanisms to structure consultation between researchers. Finally, there is a National Academy of Sciences and Techniques which represents a place of recognition of academic knowledge generated by national researchers. Human resources dedicated to research for innovation are structured by the following main institutions (Table 4).

However, on the quality aspect of governance, it remains important to talk about clientelism. The Senegalese economy is a rentier economy. Behaviour to increase labour productivity is rare. In order to create a learning society, the political elite must be able to provide leadership on the management of public goods. This leadership requires a realistic and achievable vision of the country's development. The new social contract defined since 2000 should have encouraged this vision. On the contrary, this new regime has led to the development of political formations dominated, in the main, by the rentier elites (Diallo, 2004). Universal clientelism is still

very much alive. Untrained government teams cannot grasp the innovative dynamics and identify the difficulties and information needed to make decisions. The action of the state is thereby distorted and devoid of any virtue and of a quest for rationality. It is not surprising that economic, social and cultural issues occupy few places in the political programs of leaders (Dieng, 2000). The consequences of this situation reflect an anti-political culture that leads to substitutes for anti-state parties and NGOs. In this perspective, the country's corruption index (2020) is 29 out of a total of 45 countries. Much progress is yet to be made on this point.

Learning Policies

Since 2013, Senegal has been conducting a Quality, Equity and Transparency Improvement Program in order to plan the main school and poverty reduction reforms until 2025. The program aims to achieve universal primary schooling, equitable access by gender, poverty reduction and skills training for youth and adults. This program, set up after the Ten-Year Education and Training Program (PDEF), aims to catch up on training and education delays in comparison with other developing economies. The country's total literacy rate in 2017 was 69.5% of which 75.6% for men and 63.5% for women (UNESCO, 2015). These figures are constantly being revised upwards. Thus, the main difficulties encountered in education and learning are as follows (PAQUET Report, Ministry of National Education of Senegal, 2013):

- High cost of schooling (beyond tuition and transport), which explains a massive exit from the school system beyond the college and which affects women in particular
- Inadequate reception facilities and deprivation in which a large number of public establishments are located
- Difficulty of the state to pay regularly the salaries of the growing number of teachers and supervisory staff
- Initial training of teachers sometimes recruited after the baccalaureate

Therefore, to remedy this, the general orientations of PAQUET-EF 2018–2030 pursue the objectives of quality, equity and good governance initially set but reinforce their emphasis on equity of access by reducing vulnerabilities, the development of preschool and the consolidation of the fundamental cycle by integrating all forms of education (including non-formal) and by developing bridges, in particular through the development of vocational guidance systems to promote orientation towards professional fields and techniques.

Senegalese higher education welcomed 160,000 students to its network of universities and higher education institutions in 2017–2018 (French Embassy in Senegal, 2017). The significant demographic growth of Senegal and the increase in gross enrolment rates and the number of girls in secondary education have greatly increased the demand for access to higher education. Despite a low success rate for the baccalaureate (35.9% in 2018), the annual flow of baccalaureate holders is constantly increasing, rising from around 9000 in 2000 to more than 53,273 candidates admitted for the 2018 session. Eighty per cent of

holders of the baccalaureate enrol in Senegalese higher education thus implying serious problems of overstaffing (French Embassy in Senegal, 2017). Projections made by the Ministry of Education, Research and Innovation (MESRI) estimate the student population at 270,000 students in 2022, the goal being to reach 700,000 students by 2027.

Several universities have thus emerged:

- University of Sine Saloum El Hadj Ibrahima Niass (USSEIN): It opened in February 2019 with a cohort of 1725 students. It provides training in agriculture and related professions, for food security, sustainable development and prosperity.
- Amadou Mokhtar Mbow University (UAM): Located in the new town of Diamniadio, near Dakar; its construction site began in January 2016. UAM is designed to eventually accommodate 30,000 students. It is a university mainly oriented towards science and technology.
- Virtual University of Senegal: Created in 2013, the Virtual University of Senegal offers a range of open distance learning courses in the fields of Mathematics/IT, Economic science, Legal Sciences, English and Sociology. In 2018, UVS welcomed 27,000 students, with a projection of 30,000 students in 2019, thus becoming the 2nd university in Senegal. Training is delivered through online courses and support from tutors.

If new universities emerge, the introduction of a lifelong learning policy (vocational training, company training, training leave, etc.) is made difficult in contexts of high industrial concentration and the dominant informal structure of entrepreneurship within a fabric of small and micro enterprises. In Senegal, this policy is trying to develop with the creation of institutions such as ISADE (Institut Supérieur Africain pour le Développement de l'Entreprise). Another constraint is posed by the difficulty of the firms to have centers of formation connected to the system of academic education. The main sources of learning are on-the-job and informal (Casadella, 2010). They are poorly adapted (content, speed ...) to the absorption of knowledge of technologies that offer the globalization of knowledge related to the digital revolution. The rapid and efficient use of new technologies by a skilled workforce thus requires investment in the training of technological engineering.

As such and since 2014, a new fund, the 3FPT, supports the initial and continuing training of workers in companies and professional organizations, young people seeking qualifications, training centers and institutions but also the quality assurance of vocational and technical training system. This fund is particularly significant, even if it trained just over 18,000 Senegalese in 2018. In this dimension, and following a remarkable weakness in the number of learners in technological professional fields and an imbalance in training levels. Macky Sall asked in 2013 to reorient the higher education system towards science, technology, short vocational training. It has established Higher Institutes of Vocational Education (called "ISEP") in all regions of the country. The educational project of all ISEPs is based on the skills-based approach and leads to the Higher Diploma of Vocational Education at Bac+2 level, with a study-workplace alternation. This fund and these institutes are particularly important for the development of learning and competencies. They make it possible to create more demand for knowledge, in a context of professionalization and rapid acquisition of knowledge.

If Senegal has initiated deep reforms in favour of higher education and its professionalization, it is not only to turn to a more suitable labour market but also to avoid a massive brain drain. Each year, the migration of Senegalese students is increasingly strong and concerns more a qualified population. According to UNESCO data, there are 13,876 mobile students abroad (including almost 9000 in France), i.e. a rate of mobility abroad of 7.5%. In sub-Saharan Africa, more broadly, the brain drain is very pronounced and could reach 34 million immigrants in 2050 (IMF Report, 2016). The government has therefore acted positively by proposing the construction of new higher establishments, including ISEPs geared towards vocational education. Senegal has also initiated a specific program for the assistance and supervision of its qualified immigrants and created the post of Special Advisor on Immigration to the President of the Republic. Inter-university cooperation has finally been strengthened.

Research & Development (R&D) Policies

The Structural Adjustment Policies of the 1980s destabilized government strategies for investment in scientific and technological capacities and public infrastructure that secured access to water, energy and transport investments. Since the 2000s, they have been renewed in favour of innovation. Implementation in Senegal of the Poverty Reduction Strategy (PRS) of integrated programs, such as the “National Strategy for Economic and Social Development” since 2013, but also the strategic objectives of increasing the budget for R&D and the strengthening of South-South and North–South scientific cooperation are salutary changes for the years to come. A National Consultation on the Future of Higher Education, Research and Innovation was completed in 2013 with a “Priority Reform Program 2013–2017 for Higher Education and Research in Senegal” and a “Plan for the Development of Higher Education and Research”. Since then, and in the latest report “Emerging Senegal Plan 2019–2023”, the government is betting on a clear increase in R&D spending: “The performance recorded will be measured against the percentage of spending allocated to research and development on the GDP, a percentage which should drop from 0.8% in 2015 to 3.98% in 2023” (Emerging Senegal Plan, 2018). According to the 2015 UNESCO Science Report, the domestic research and development expenditure of Africa in 2013 accounted for 0.45% of GDP. This corresponded to 1.3% of global research and development spending while Asia’s share was 42% in the same year. Although the state is generally the main source of GERD, foreign funding represents a significant share in Ghana (31%), Senegal (41%) and Burkina Faso (60%) (Unesco, 2015). In Senegal, research funding remains mainly oriented towards R&D in the agricultural and food sector (about CFAF 1 billion for agricultural R & D, compared with about 600 million for industrial R&D) and foreign funds.

Sectoral, Regional S&T Policies

Other structures act directly indirectly on S&T but provide support for entrepreneurship:

- The agency for the development and supervision of small and medium-sized enterprises (called ADEPME) supports the manager throughout the life of their business: the creation or resumption of an activity, business growth or restructuring.
- The mission of the General Delegation for Rapid Entrepreneurship for Women and Youth is to help boost entrepreneurship among women and young people. Informal entrepreneurship occupies a preponderant place in the Senegalese economy and its formalization promotes the inclusion of women and young people, targets generally marginalized by the traditional financial system. Along with these structures, new “learning” projects emerge such as the Sonatel Academy, the first free coding school in Senegal, which aims to become a point of innovation throughout the value chain, with a school, the Fab Lab, a start-up space, which supports the school’s laureates through a personalized acceleration program.

Technological innovation is also promoted by a system of more favourable regulations. In this sense, at the end of 2019, a law on the Start-up Act relates to the creation of a specific support and governance framework for startups under Senegalese law, the establishment of a legal regime adapted to the registration and labelling of Senegalese startups, the creation of a resource center dedicated to Senegalese startups, in particular to facilitate labelling procedures as well as the effectiveness of the support mechanisms put in place. It also offers a set of relevant incentives that align with the imperative of promoting and supporting the development of the Senegalese startup.

At the sectoral level, there are clear advances in the telecommunications and digital innovation sector. The Orange Sonatel group recently inaugurated the Orange Digital Center in Dakar. This third place of innovation supports entrepreneurs, from training to technical support to investment. Fablabs in the heart of Dakar were recently opened (DefkoAkniep). The Senegal Digital Strategy 2016–2025 (SN2025) aims to accelerate the deployment of IT infrastructure, beyond the current level of service quality and cost competitiveness. The country is committed to building a digital technology park in Diamniadio (45 min from central Dakar) and developing a business-friendly tax policy to catalyse foreign investment in the sector. Thus, Senegal is the main supplier of IT services and the leading provider in the outsourcing of business processes in French-speaking sub-Saharan Africa (Ministry of Commerce, Senegal, 2018).

Finally, at the regional level, within the framework of WAEMU and the African Industrial Property Organization, the Senegalese Agency for Industrial Property and Technological Innovation (called ASPIT) supervises and supports innovative projects while subsidizing them when projects are promising.

In total, we can sum up the efforts relating to S&T policy as follows (Table 5).

2. Culture and demand of learning

We have grouped these two variables because they are difficult to assess from secondary data. Learning culture refers to in-company training, which is particularly difficult to quantify in an economy where informality is notorious. This variable therefore requires a more in-depth field study in a given sector or territory.

Table 5 Identification of ST policies on different levels of analysis

National efforts	Sectoral efforts	Regional efforts
Direct: Low R&D spending but average for sub-Saharan countries Relatively low scientific output Regulatory incentives favourable to innovation	Rapid promotion of new information and communication technologies (hubs, fablabs) Entrepreneurship support mechanisms	Subsidies, incentives for patents within the WAEMU
Indirect: Creation of several new universities, higher education establishments Strengthening inter-university cooperation		

Source: authors

On the demand for learning, two points should be noted: the nature of the labour markets and the number of research professors. The labour markets are saturated and the professional integration of young doctors in Senegal is a real obstacle course, due to poor management of institutions and lack of supervision and lack of financial means (Doucouré, 2014).

The demand for qualified personnel in the public sector (public and private higher education) can be assessed through the national recruitment of research professors. However, data on R&D in the private sector are not available and remain only appreciable in the agricultural sector, which is representative of overall R&D. Because many Senegalese companies face limited competition, nothing prevents them from investing in R&D. But most do not have a long-term view of the potential benefits of research, and many find it unnecessary to invest because new technologies will come to them from the public sector or from abroad. As their R&D resources are modest in terms of infrastructure, only a few maintain research staff and, if necessary, the available staff is very low.

According to the Higher Ministry of Higher Education, Research and Innovation (2019), the staff of research professors is 1757 men and 302 women (2017 statistics) in the public sector and 250 permanent male teachers in the private sector and 85 women. According to the Higher Ministry of Higher Education, Research and Innovation (2019), the staff of research professors is 1757 men and 302 women (2017 statistics) in the public sector and 250 permanent male teachers in the private sector and 85 women. These data mark the insufficiency of research teaching staff, in comparison with other African economies such as Cameroon, which certainly does not have the same population and student density, but which exceeds 4400 research professors in the public.

3. Learning links

In a context of public policy reform to build national innovation systems, stakeholder action is being challenged. It can be analysed by focusing on collaborations between institutions dedicated to training, learning capacities and undertakings without claiming to deal with the exhaustiveness of the interactions that it would be necessary to analyse.

“Horizontal collaborations” (actors with the same function between firms) often take on an informal aspect in developing economies. Tacit (uncodified) knowledge is transmitted or formed within learning processes and non-market domestic social institutions. The information systems adapted to the needs of the entrepreneurial sector on the resources proposed by national research in terms of new knowledge, results and training capacity have yet to be built.

The “vertical collaborations” between companies and training institutions focus on the conditions for the mobilization of knowledge are codified. They are transmitted in institutionalized learning in universities, research centres or any other service activities. These learning are at the centre of technological absorption mechanisms that mobilize globalized technologies and knowledge.

These vertical collaborations are weakened by several dysfunctions revealed by the works available mainly on the weakness of the courses of technological

engineering in academic courses very academic and the lack of finalization of research orientations or training offers in the light of the entrepreneurial demands. A major difficulty is to be able to respond to the need for transformation of technological accompaniment within the informal sector. Faced with the difficulty of public structures to accompany learning processes, skills training carried out by the informal sector, NGOs and private companies via business counselling increase their services in this direction. Their flexibility of intervention makes it possible to better respond to the specificity of local demands. Nevertheless, the creation of coherence in their intervention with the ongoing renewal of public action in higher education is solicited by numerous studies (Fofiri et al., 2015).

In Senegal, not only are relations between enterprises and administrations complex and ambiguous, but there is a wide opposition between the logics of companies, research institutes and business support institutions (Carre, 2002). More generally, the absence of an adequate research ecosystem does not allow researchers to flourish. It is at the origin of the qualitative and quantitative weakness of research work, the flight of trained talents and the weak situation in which African researchers currently find themselves in cooperation and collaboration with their partners in developed countries (AUF, 2019).

4. Local readaptation of knowledge

Real Efforts in Indirect Innovation Policies Extensive efforts have been made by the Senegalese government. These efforts do not concern policies for technological innovation through R&D (apart from the promises made by the government to exceed 1% of Gross Domestic Product), but more indirectly through learning policies or the promotion of key sectors such as digital or entrepreneurship. We also note the participation of several ministries (Commerce/Education/Economy) to deal with these issues.

On higher education, the Emerging Senegal Plan, for example, integrated the desire to develop higher education by supporting the objective of making Dakar an integrated benchmark campus with the creation of at least five schools of international fame. The objective is to strengthen the supply of specialized higher education centred on key sectors of the economic emergence of Senegal and the sub-region and to promote poles of excellence (French Embassy in Senegal, 2019). On the promotion of entrepreneurship, the creation of incubators to encourage Information and Communication Technologies (ICT), or ADEPME which sets up a shared-cost fund intended to partially finance non-financial services, including active small- and medium-sized enterprises in ICT, show here too the will of the state to remain leader in its region in the digital sector. While these aspects are very encouraging, it is nevertheless important to respond to the rapid massification of higher education and the problem of financing innovation, which is still difficult (in particular by the presence of 97% of informal structures) (Ministry of Commerce, Senegal, 2018). In addition, as the country suffers from a weakness in technology transmission through foreign direct investment and from fragile and

unstructured links between actors in the innovation process, it remains important to continue reforming learning institutions and clarifying the architecture of the Senegalese innovation system, too crumbled and scattered.

5. Inclusive innovations

The Implications in Terms of Economic Development Remain Low but Promising Policies and regulations can create obstacles and restrictions that sometimes pose a hindrance to innovation (Patanakul & Pinto, 2014). In the context of Senegal, it is the macroeconomic conditions that are not favourable to innovation and therefore to growth and economic development. The unemployment rate, the economic dependence of the country, the very significant clientelism, the political context linked to the questioning of democratic principles (following the arrest of an opponent in power) are not favourable to a context of learning and skills creation. Non-formal learning is problematic and remains the dominant form of mastering new technologies (Oyelaran-Oyeyinka & Lal, 2006). In addition, the contribution to R&D is low and not representative of Senegalese growth. We must therefore both modernize knowledge while orienting priorities not towards R&D but towards promising sectors.

Inclusion must therefore be directed towards promising sectors while continuing to develop higher education to train qualified employees and reduce the brain drain.

Among the promising sectors previously mentioned: digital or entrepreneurship. And in this sense, the inclusion of Senegal through the digital economy has been a priority set in the national strategic development framework, the “ESP”. The Senegal Digital 2025 strategy also aims to accelerate the deployment of IT infrastructure, which has already reached a high level both in terms of service quality and cost competitiveness. In addition, the country is committed to building a digital technology park and developing a business-friendly tax policy to catalyse foreign investment in the sector. More locally, the Orange Digital Center, which enriches an integrated Senegalese digital ecosystem where public and private actors help, make the country a regional digital hub.

It is therefore not the small contribution to R&D that has a positive effect on economic development, but the various sectoral impulses and learning policies. The importance in this country is therefore given to indirect innovation policies.

Conclusion

The assessment of works on NIS in low- and middle-income countries provides us with two main conclusions:

The first is methodological. If these NIS do not improve, we should first ask the question “who and how were these defined originally?” First, they should be interpreted in a broad sense and therefore defined according to what they really represent and not what they should manage to achieve according to experts or

international organisations (hence the question of the relevance of quantitative indicators of S&T), but mainly they should no longer exist as a purpose, but as a way of improving the living conditions of the population concerned. Hence, the many structural errors largely mentioned in the literature could be transformed into real questions on the opportunities/conditions to create knowledge. In the case of Senegal, sectoral, local and national initiatives are commendable and investment in ICTs makes it possible to create knowledge at the level of the population, to democratize new technologies, just as entrepreneurship can improve living conditions of women.

The second is theoretical. The theories of learning are no longer to be proven in this approach. However, it is what they integrate within them that needs to be better defined, better circumscribed. For this, it is a question of better understanding the heterogeneity of the NIS of low-income and middle-income countries through the diversity and richness of their learning techniques (Johnson and Lundvall., 2003). While there is large international data on R&D, patents, licenses, or formal levels of education, it is more difficult to understand how systems in low- and middle-income countries learn, beyond the usual techniques of education. And to grasp it, we must analyse the amount of energy spent by the actors in solving problems, but also the knowledge that the actors have in mastering new knowledge. It is about efforts and trajectories of use of local knowledge by the capacity to (be able to) internalize foreign knowledge. The domestication of knowledge, rehabilitation and local reappropriation are at the heart of the challenges of the NIS of these economies.

In addition, we can make several recommendations in terms of public innovation policies in the case of Senegal:

- Encourage innovation ‘in the broad sense’ by continuing to promote promising sectors on which the country is strategically oriented (such as new technologies: fablabs, ecosystems, incubators) without seeking to reproduce models imported from industrialized countries.
- Further democratize higher education, and, beyond higher education, learning policies in the broad sense (lifelong learning policies, early learning structures). The country is on an excellent way in terms of apprenticeship reforms, but must still focus on education, as specified in goal 4 of the Sustainable Development Goals set by the UN in 2015.
- If R&D is only a small contributor to economic development, as in most African countries, the lessons to be learned can only be directed towards the establishment of bottom-up, local, sectoral policies which seek, among other things, to give meaning to the informal without attempting to formalize it, but rather by seeking to know where skills are created in order to enhance them. Economic development can only improve when political governments will orient their innovation policies on the real expectations and needs of the population and not on the basis of recommendations from R&D experts from imported innovation policies.

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