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National systems of innovations are "x-efficient" (and x-effective) Why some are slow learners☆

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Abstract

The growing literature on national systems of innovations (NSIs) are creating a crucial new perspective on the institutional infrastructure of the knowledge-based economy. However, this literature tends to be somewhat optimistic: it often takes for granted that NSIs are sets of institutions facilitating learning, particularly about technology and organization. This paper reconsiders the efficiency of NSIs. It suggests that NSIs are "x-inefficient" (and x-effective). It develops some of the major factors explaining inefficiencies and proposes methods to measure the efficiency and effectiveness of NSIs. It offers some examples of inefficiencies from a comparison between selected NSIs, and suggests indicators of efficiency and effectiveness.

Keywords: NSIs; Benchmarking; QWERTY

1. NSIs, institutions and linkages

Since its original formulation over a decade ago, the concept of national systems of innovations (NSIs) have attracted the attention of many researchers working in institutional economics and innovation, as well as policy makers of both developed and developing countries (Amable et al., 1997; Correa, 1998; Foray, 1994; Freeman, 1988, 1997; Lundvall, 1998; Nelson, 1988, 1992, 1993; Niosi, 1991; Saviotti, 1996). Its usefulness in the description of the institutions devoted to innovation is beyond question.

Although no single definition has yet imposed itself, there is a semantic core that appears in most of the definitions used. Table 1 outlines some of the present definitions. As Edquist has pointed out, the institutional set-up related to innovation, and the underlying production system, are the basic characteristics of NSIs (Edquist, 1997, p. 15).

NSIs is thus a set of interrelated institutions; its core is made up of those institutions that produce, diffuse and adapt new technical knowledge, be they industrial firms, universities, or government agencies. The links between these institutions consist of flows: knowledge, financial, human (people being the bearers of tacit knowledge and know-how), regulatory, and commercial.

The concept of NSIs has been expanded towards that of "systems of innovations" (SIs). There are clearly industrial, local, regional, national, and may be international SIs. Which level is to be privileged, if any? I have a few arguments in favor of the focus on national and regional (subnational) SIs, based on both evolutionary economics and common sense on the mobility of production factors. Capital easily crosses

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Table 1
Definition of NSIs

"... The network of institutions in the public- and private-sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (Freeman, 1987)
"... The elements and relationships which interact in the production, diffusion and use of new, and economically useful knowledge ... and are either located within or rooted inside the borders of a nation state" (Lundvall, 1992)
"... The set of institutions whose interactions determine the innovative performance of national firms" (Nelson and Rosenberg, 1993)
"... The national system of innovation is constituted by the institutions and economic structures affecting the rate and direction of technological change in the society" (Edquist and Lundvall, 1993)
"... A national system of innovation is the system of interacting private and public firms (either large or small), universities, and government agencies aiming at the production of science and technology within national borders. Interaction among these units may be technical, commercial, legal, social, and financial, in as much as the goal of the interaction is the development, protection, financing or regulation of new science and technology" (Niosi et al., 1993)
"... The national institutions, their incentive structures and their competencies, that determine the rate and direction of technological learning (or the volume and composition of change generating activities) in a country" (Patel and Pavitt, 1994)
"... That set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artifacts which define new technologies" (Metcalfe, 1995)

national or regional boundaries. Knowledge flows less easily, because of the tacit character of much of it, which is embodied in human brains. Human capital means tacit knowledge, which is difficult to transfer without moving people. The less mobile factors of production and the most crucial for innovation are human capital, governmental regulations, public and semi-public institutions, and natural resources. For all these factors borders and location matter.

The building blocks of NSIs are institutions and linkages. First, "institutions are set of habits, routines, rules, norms and laws, which regulate the relations between people, and shape social interaction" (Johnson, 1992, p. 26). Private firms, universities, government laboratories and other public agencies are referred here as formal institutions or organizations.

Institutions (formal or not) provide incentives, information and resources, reduce uncertainty, and attenuate conflicts (Edquist and Johnson, 1997, p. 55). This brief description allows for the possibility that some institutions involved in innovation may provide the wrong incentives, faulty information, or allocate insufficient resources to accomplish their goals or mandates; they may fuel conflicts and they may fail to reduce uncertainty.

Secondly, linkages and flows (which may or may not occur) include financial flows between government and private organizations (such as emerging industrial enterprises and venture capital firms), human flows between universities, firms, and government laboratories, regulation flows emanating from government agencies towards innovative organizations, and knowledge flows (spillovers) among these institutions. Their characteristics may assist or be detrimental to the smooth and efficient operation of the NSIs.

2. NSIs as "x-efficient" (and x-effective) learning systems

Learning, particularly interactive learning, has been the leitmotif of NSIs from the start. NSIs are the learning systems of national economies (Lundvall, 1988, 1992, 1996). The conditions of making learning more effective or simply feasible within organizations have long been studied by management science (Argyris, 1992; Dodgson, 1993; Nonaka and Takeuchi, 1996). More recently, government learning has been also examined: their specific organizational characteristics may make government institutions unable to learn (Gick, 1997, 1998). "In bureaucracies, individuals may pursue long-term career plans by following conservative attitudes; often internal controls and the decision-making structures offer a hostile climate for any experimental behavior" (Gick, 1998, p. 279).

Since Leibenstein (1976) wrote, we have known that firms are x-efficient: they are not operating optimally, but their level of efficiency is variable, depending on their internal organization and accumulated knowledge. In the meantime, evolutionary economics and management science have shown that agents, being bounded rational, do not maximize, but "satisfy", usually below any optimal level of efficiency. We realize that governmental organizations may or may not learn. Like firms, NSIs are thus also x-efficient.

Definition 1. The "x-inefficiency" is the gap between observed performance and existing best performance (maximum output observed in equivalent organizations). It is not the gap between observed performance and any optimal, theoretically determined performance.

It is also possible to argue that NSIs and their institutions are x-effective.

Definition 2. The x-effectiveness is the degree at which institutions attain their organizational missions. Examples of typical missions are: university producing human capital (graduates); producing basic scientific knowledge; transferring that knowledge to society. Government laboratories: conducting applied R&D; transferring that knowledge to society.

Some organs in any individual can and do perform better than others. Some institutions can also perform better than others: some universities are better at producing new knowledge or graduates, some firms are better at managing new product development, some government laboratories are more efficient in transferring technology to industry, and so on.[1] Thus, institutional efficiency appears as a variable when similar institutions are compared with one another with similar missions, not when a given institution is compared to an optimum. The practice of comparing firm's efficiency and practices is well established in management: it is called "benchmarking".

Neoclassical economics has already shown that markets may be inefficient. Externalities ("spillovers") are the most frequent type of market failures. Equilibrium economics has also shown that governments can fail. Economic policies that maximize the welfare of small, powerful interest groups, while reducing the welfare of the majority, represent government failures. Now we can observe that there are other types of inefficiencies, related to both institutions (Section 2.2) and systems (Section 2.3) and considers the possibility of addressing them through benchmarking (Section 3).

2.1. Path-dependence and lock-in

Most of the inefficiencies and ineffectiveness of national innovation systems may be related to path-dependence and lock-in situations, such as characterized by evolutionary and historical economics Magnusson and Ottosson (1997). In a simple way, path-dependence processes are characterized as "those phenomena whose outcomes can only be understood as part of a historical process" (Rosenberg, 1994, p. 205). Those outcomes are not necessarily optimal.

The central explanations of path-dependence include the following (Arthur, 1994; David, 1985, 1988, 1994).

1. Increasing returns to scale: in industries characterized by increasing returns, the first firms to enter may impose their technology, and thus dominate the market. New entrants will start under lower production scales and less experience thus higher costs.
2. Networks externalities: early entrants may diffuse their standards (think of software or video-cassette recorders) and exclude future competitors, whatever the quality of their technical solutions.
3. Sunk costs: existing firms may get locked-in their technology due to past investments in equipment and machinery.

   While these explanations concern mainly technology and industry, other complementary factors should be added to explain why institutions and organizations get locked into sub-optimal solutions.
4. Contracts: institutions are devices that reduce uncertainty, and contracts tend to make explicit both

[1] The SIs literature takes an ambiguous stand on efficiency. In Lundvall's seminal work, "we would like to propose that the most relevant performance indicators on NSIs should reflect the efficiency and effectiveness in producing, diffusing and exploiting economically useful knowledge. Such indicators are not well developed today" (Lundvall, 1992, p. 6). However, ideas later changed. A recent book suggests that "neither we can argue that one country spends much on R&D or that its system performs well or badly. This is because the notion of optimality is absent from the system of innovation approaches. Hence comparisons between an existing system and an ideal system are not possible" (Edquist, 1997, p. 20). Later, in the same book, however, institutions are eventual obstacles to innovation, without further elaboration (Edquist and Johnson, 1997, p. 55).

expectations and performance requirements. However, contracts tend to "freeze" organizations. The cost of radically changing existing contracts may be particularly high.
5. Human learning: organizations invest in codes of communication, human capabilities and the like. These are sunk costs of a specific, intangible type. They are unrecoverable, so that firms and other organizations having invested in a specific technological and organizational trajectory may experience difficulties in changing it.
6. Economic systems may display multiple equilibria, including multiple organizational equilibria. Different types of institutions (firms, universities, public laboratories and policy incentives) can yield similar outcomes. In that case, even if each set of institutions serves well in different economic environments, all may not be equally efficient. Also, if some types of organizations were the fittest at a given moment, they were so in regard to a particular selection environment; they are not the fittest for all. Thus, the possibility that some organizations remain "locked-in" specific characteristics that were efficient or effective in time t_1, but are not "optimal" forever and may thus be inefficient and/or ineffective in time t_2 (Hodgson, 1996).

Inefficiency and ineffectiveness have several, deeper origins. According to Antonelli (1997) "path-dependence is generated by the overlapping of irreversibility, indivisibility and structural actions of agents". First, sunk costs of all types, both in equipment and learning, are linked to irreversibility: under new, more performing technologies or organizational codes, sunk costs generate unanticipated obsolescence. Organizations tend to stick to their own obsolescence plans, particularly if they are uncertain about the gains to be realized by the abandonment of existing technologies or organization, and the adoption of the new ones. Second, in the case of massive network externalities and large equipment facilities (such as those generated by millions of users of a software operating system, or large electrical plants), indivisibility also contributes to path-dependent processes. Finally, in a world of uncertainty, nobody knows the best way of solving the problems that we face, and nobody would maximize utilities (North, 1990, p. 108). North anchors this argument on severe bounded rationality: when people do not have adequate information about best practices, they stick to what they know thus generating path-dependence.

Also, feed-back effects reinforce path-dependence. Nobel Prize winner Gunnar Myrdall has shown that there are often lock-in conditions in developing countries, based on feed-back effects (Myrdall, 1956). These are situations where institutional inefficiency is severe and difficult to correct: vicious circles of poverty, deficient educational systems, political corruption, low savings and investment, all reinforcing each other.

Finally, March (1994) suggests that lags in time may be important; adaptation to best practices may take time, and there is not even the assurance that better performances will ever take place, after the adoption of the organization or technology, or that convergence will occur. Causal ambiguity reinforces the technological and organizational trajectories.

Williamson admits that path-dependence and history are significant. He underscores nevertheless that the maximizing behavior of agents under appropriate inducements, such as changing prices or demand patterns) may be enough to break the path-dependent process. "That history matters does not, however, imply that only history matters. Intentionality and economizing explain a lot of what is going out there" (Williamson, 1998, p. 50). Also, some of the inefficiencies are remediable, others have negligible effects, such as the choice of the VHS over the Beta video-recording systems, or the QWERTY versus the Dvorak keyboards. Williamson accepts, though, that there exist large and irremediable inefficiencies, and that they "do raise serious issues for modeling economic organization" (Williamson, 1998, p. 51), such as those that Myrdall has studied related to chronic underdevelopment. Williamson adds that there are technological trajectories as well as organizational path dependencies, the latter may be the most important.

This analysis brings us to NSIs. In different countries, they may be composed by very dissimilar institutions (multiple equilibria), created under different historical circumstances. In a dynamic environment, the evolution of these institutions may lag in time, be frozen by contracts and past investments, and remain maladapted to new performance requirements. Institutions may not be changed because decision-makers do not know foreign best practices, or even other practices (bonded rationality). Also, some of the institutions (government laboratories, universities, and policy-making agencies) are often "out of the market", they enjoy monopoly positions and are thus isolated from the type of maximizing behavior that Williamson has pinpointed.

2.2. Sources of institutional inefficiencies

Contrary to what neoclassical economics argues, institutions are not neutral and optimal black boxes, but x-efficient organizations. Inefficiency derives centrally from the fact that institutions are intimately connected with past environments, not with any future state of the world (David, 1994). Thus, they may be inapt to treat future states of that environment. Inefficient institutions, like the QWERTY keyboard, may become locked in a specific shape linked to previous states. Sources of institutional inefficiencies include at least four types.

- Organizational inertia: flawed founding structures may impede organization's ability to adapt to a changing environment or to adopt current best practices. Some currents of the evolutionary economics and management tradition have insisted on the importance of organizational inertia in explaining the turnover of firms in different industries (Hannan and Freeman, 1984; Carroll and Hannan, 1995). Walker (1993, p. 178) suggested that the Britain's NSIs has historically hampered by poor education and training, a situation that had begun when it did not rely on mass education for its early industrialization, and neglected educational institutions.
- Badly designed contracts and information asymmetries: employees under contracts with inadequate time frames, incentives, or rewards may not provide their best efforts at work. Contract theory is now a major current in economics and management. Based on the work of Arrow (1974) and Williamson (1975) it has become a full-fledged chapter of the theory of the firm and organizations (Holmstrom and Tirole, 1989). Crow and Bozeman (1998) have developed measures of bureaucratization of research and development (R&D) laboratories in the US NSIs, and how it has influenced contract effectiveness.
- Lack of appropriate learning routines: R&D activities, and/or retraining schemes may be absent from industry, reducing its absorptive capabilities (Cohen and Levinthal, 1990). A common characteristic of the three largest NSIs in Latin America (Brazil, Mexico, and Argentina) is the weak diffusion of R&D routines in private industry. Industrial expenditure on R&D in these nations is usually less than 0.1% of total gross domestic product (GDP) (Dahlman and Frischtak, 1993; Mexico, 1995; Katz and Bercovich, 1993).

The systematic comparison of costs within and between NSIs (i.e. costs of producing patents in a given industry, scientific publications, or university graduates) may reveal hidden inefficiencies inside NSIs or its institutions (see Table 4).

2.3. Sources of institutional ineffectiveness

Neoclassical economics confounds efficiency and effectiveness, supposing that all institutions have a similar (profit maximizing) behavior. However, we know that formal organizations, even firms, have different goals. Some firms aim at increasing profit maximization in the short run, while others tend to increase market share at the expense of short-term profits. The main mission of undergraduate universities is to produce first-cycle graduates, less so high-level publications or patents. The mission of research universities is more concentrated in this latter area. The goal of some government laboratories is to produce technical services, while others tend to create technological novelty and spin-off niche firms. Only organizations with comparable missions should be the object of adequate benchmarking.

Institutions attain their missions at various degrees. Sources of ineffectiveness include:

- lack of appropriate internal resources devoted to the attainment of mission. Crow and Bozeman (1998) have shown that several US government laboratories, supposed to transfer technology to the private-sector, devoted insufficient resources to that mission and thus were unable to fill it properly;
- lack of appropriate system resources devoted to the mission. The same can be said of NSIs. Argentina and Canada both show a similar total university student enrollment between 800,000 and 850,000.

Canada, however, graduates some 180,000 every year against some 35,000 in Argentina. Close to 50% of Canadian university students benefit from government fellowships or loan fellowships, against less than 1% of Argentinean students.

The comparison of institutional missions within and between NSIs (i.e. number of patents in a given industry or scientific publications per researcher, or university graduates as a percentage of new enrollment) may reveal hidden ineffectiveness in NSIs or its institutions (see Table 4).

2.4. Sources of system inefficiencies

Inefficiencies may affect the whole NSIs as well as individual institutions. [2] Such system inefficiencies include the following five factors.

- Inadequate system rules: these may include incomplete intellectual property legislation, for example, in as patent or copyright protection, and inadequate laws on corporate disclosure. In analyzing Brazil's NSIs, Dahlman and Frischtak (1993, p. 431) suggested that government controls and restrictions on technology transfer from abroad, as well as inadequate protection of intellectual property may have inhibited importation of the best technologies to that country. Similarly, also, the exclusion of non-US corporations from publicly funded American technology projects, as well as the exclusion of non-EU firms from similar European projects could reduce mutual learning and technical progress, Mowery (1998).
- Lack or limited number of key institutions: this may occur within the NSIs. Some of them lack research universities, government laboratories, or technological observatories. In his analysis of Italy's NSIs, Malerba (1993, p. 250) noted among its limitations the low number of new high-technology firms. The marginal importance of research universities and government laboratories may explain such low numbers.
- Weak coordination among units: this may include badly coordinated supply of and demand for university graduates, and lack of public incentives for firms to cooperate with industry or with government laboratories. Edquist and Lundvall (1993, pp. 290–291) pointed out the vulnerability of the Danish NSIs resulting from the absence of coordinating agencies. Poor coordination among institutions has also been mentioned to explain slow technological learning in the British NSIs (Walker, 1993, p. 180).
- Lack of information flows: such flows are essential among complementary units, for example, between firms and technological observatories or public laboratories. Teubal underlined the lack of technological diffusion from military to civilian industries in Israel, as well as from foreign sources to local small- and medium-sized enterprises (SMEs) (Teubal, 1993, p. 495).

The study of flows (including knowledge spillovers, financial flows for innovation) within and across NSIs may reveal system inefficiencies and ineffectiveness.

3. Benchmarking

Efficiency and effectiveness have to be seized not by exercises of Euclidean geometry but, as in biology and management science, through careful empirical analysis and comparison of institutions with similar missions, or "benchmarking".

Definition 3. Benchmarking is the systematic observation of organizational routines and the comparison of performance with superior units at the levels of resource use and efficiency and effectiveness (inputs and outputs). "Benchmarking is the search for industry's best practices that lead to superior performance" (Bogan and English, 1994, p. 4).

Corporate benchmarking—the development of indicators of comparative performance—started in the late-1970s and early-1980s in Xerox Corporation, as a method to monitor competitors' behavior and adopt best practices from leading companies. The public-sector, isolated from the pressures of competition, adopted benchmarking a decade later. In the mid-1980s and early-1990s, American municipalities, were producing measures of efficiency, effectiveness,

[2] A recent OECD paper (OECD, 1997) has called them "system failures", using the neoclassical analogy with market failures and government failures.

and productivity (Ammons, 1996). By the mid- and late-1990s several countries were also internationally benchmarking government infrastructure. Australia's benchmarking was in areas such as electricity, shipping, gas supply and railway freight. The exercise had a major impact in the reform of Australian infrastructures (Lawrence et al., 1997). Also, in the 1990s public school performance was benchmarked in the US (Dopuch and Gupta, 1997). International public policy benchmarking was proposed as a new method to nurture an enabling environment for both local and foreign investment (Oberhansli, 1997).

Table 2
Share of mainstream journal articles 1994 (percent of total for all nations)[a]

Country	Share of world articles	Population (1994)	Articles per million population
US	30817	263	117
Japan	8244	125	66
UK	7924	58	137
Germany	7184	82	88
France	5653	58	97
Canada	4302	30	143
Russia	4092	147	28
Italy	3394	57	60
The Netherlands	2283	16	143
Australia	2152	18	120
Spain	2028	40	51
Sweden	1841	9	205
India	1643	936	2
Switzerland	1640	7	234
China	1339	1221	1
Israel	1074	6	179
Belgium	1059	10	106
Denmark	962	5	192
Poland	913	38	24
Taiwan	805	21	38
Finland	793	5	158
Austria	652	8	81
Brazil	646	162	4
Ukraine	578	51	11
Norway	569	4	142
South Korea	546	45	12
New Zealand	426	4	106
South Africa	415	42	10
Greece	411	10	41
Hungary	398	10	40
Argentina	352	35	10
Czechoslovakia	332	16	21
Mexico	332	94	4
Egypt	280	63	4
Turkey	243	62	4
Bulgaria	220	9	24
Hong Kong	250	6	42
Portugal	201	10	20
All other	2000		
Total, world	100700		

[a] Source: Scientific American (1995).

"Benchmarks", are indicators, or operating statistics, that reveal best practices. The analysis of superior routines needs not only these indicators, but also verbal and graphical descriptions of these routines. Benchmarking was born in industry but was afterwards adopted to analyze and improve the performance of public and quasi-public entities through the development of new indicators of efficiency, effectiveness, and productivity (Ammons, 1996). It remains to be used for analyzing the efficiency and effectiveness of NSIs.

Aggregate statistics, which are often used to compare NSIs, may reveal some types of efficiency or effectiveness; they may however, hide major inefficiencies in specific sets of institutions (for example, universities, or government laboratories) or even in crucial individual institutions. It thus may be necessary to desegregate statistics, and to build new ones, to understand some observed yet unexplained x-inefficiency of the system as a whole.

Once the comparison has been conducted, at both the institutional and system levels, and conclusions have been drawn, several possibilities may be open for both public- and private-sectors managers, including:

- redesigning existing institutions, including changing contracts, incentives, rules, or routines, in order to break inertia;
- creating new institutions, such as research universities, government laboratories or technological observatories (or closing inert ones) when necessary;
- reshaping flows, so as to create new flows of knowledge, personnel, finance or coordinate other types of flows when required.

4. Benchmarking NSIs

There are data and theoretical background on the analysis of institutional efficiency, as well as the knowledge stocks of institutions, and on flows among them. Niosi et al. (1993) proposed studying institutions by means of ratios between basic inputs (expenditures, personnel) and outputs (patents, publications, internal reports, innovations, new products), as well as analyzing their interaction via such variables as size, ownership and control, and regional distribution. One can assess monetary flows through the study of financing of innovative activities (both public and private), and technology flows by looking at citation analysis in patents, and publications, as well as licensing (when available), technological alliances and joint R&D. Personnel flows between firms, universities, and government laboratories, as well as among firms can also be measured to reveal flows of tacit knowledge. The analysis of patents and publications gives an idea of the wide differences in efficiency between NSIs which would require some explanation (Tables 2 and 3). Niosi and Bellon (1994) argued that foreign direct investment in R&D, trade statistics in high-technology, international payments for technological services, and other available figures help one assess the openness of NSIs.

More recently the OECD (1997) suggested studying knowledge flows through the diffusion and adoption of industrial technology by private firms. The diffu-

Table 3
Patents granted in the US to foreign and national inventors in 1997[a]

Country	Patents (%)	Patents per million population
US	69925 (56.3)	277
Japan	24190 (19.5)	195
Germany	7292 (5.9)	92
France	3202 (2.6)	52
UK	2904 (2.3)	50
Canada	2816 (2.3)	104
Taiwan[b]	2597 (2.1)	130
South Korea	1965 (1.6)	46
Italy	1417 (1.1)	24
Switzerland	1179 (0.9)	168
Sweden	970 (0.8)	107
The Netherlands	895 (0.7)	60
Israel	577 (0.5)	115
Australia	568 (0.5)	33
Belgium	558 (0.5)	56
Finland	468 (0.4)	94
Denmark	432 (0.3)	86
Austria	393 (0.3)	49
Spain	193 (0.16)	5
Brazil	67 (0.05)	0.4
Mexico	57 (0.05)	0.6
Argentina	38 (0.03)	1.1

[a] Selected countries; source: US patent office.
[b] Taiwan is a province of China.

Table 4
Examples of indicators of NSIs performance

	Level	Indicators (benchmarks)
Effectiveness indicators	University	University graduates as percentage of new enrollment
	University	University publication per university researcher
	Industry	Industry patents per industrial researcher
	Government policy	Number of firms conducting R&D
	Government policy	Number of research universities
Efficiency indicators	University	Cost of university graduates
	University	Cost of university publications (publications/HERD)
	Industry	Cost of industry patents (total industrial patents/BERD)
	Government laboratories	Cost of government laboratories' patents
Quality of output	All institutions	Citations to patents
	All institutions	Citations to publications
	Industry	Number of innovations
	Industry	Exports of technologically-intensive goods and services
Flows/synergy		Personnel flows among organizations
		Knowledge flows
		Technology transfer
		Technological alliances
		Machinery diffusion
		Financial flows
		Venture capital for new high-technology firms
		Government subsidies for R&D
		Regulatory flows
		Intellectual property legislation
		Legislation on standards
		Anti-trust and cooperative rules and laws
		Human flows
		University graduates supply and demand by discipline and institution
Ratios and indexes	At NSIs level	GERD/GDP
		Revealed technological advantages
		Input/output macroeconomic ratios
		Trade balances on high-technology goods and services

sion of industrial machinery—specifically advanced industrial equipment—is also a process of knowledge diffusion. Tables 4 and 5 summarizes benchmarks that have been used in the literature to highlight different dimensions of NSIs, as well as a few suggested benchmarks for efficiency and effectiveness.[3]

When benchmarking differentiates from NSIs, it seems important to bear in mind that different institutions, as well as different NSIs, have distinct missions. Comparing research universities with undergraduate higher-education institutions would lead to major errors. Similarly, mission-oriented NSIs, such as the UK, or the US, may have widely different institutions than diffusion-oriented ones, such as Denmark or Norway. Also, NSIs that are in the frontier, at least in specific areas of science and technology, should display different characteristics compared to catching-up nations, such as Korea or China. With these provisons, systematic benchmarking may lead to major discoveries and policy recommendations for amelioration and development.

[3] These and other useful indicators are produced by both national organizations (National Science Foundation in the US; l'Observatoire des sciences et des techniques in France, Statistics Canada, etc.) and international organizations (such as OECD in Paris).

Table 5
Stanford University benchmarks for comparison with other top 20, 1995[a]

Faculty	Indicators: all figures on yearly basis Demand for new faculty Salaries Percentage of faculty with tenure Retirement rates Percentage faculty with doctorates by full- and part-time Age distribution, age at first hiring, and age at retirement Distribution per category of professors (full- vs. part-time, etc.)
PhDs	PhD production by discipline Time required to complete degree PhD by citizenship Employment of PhD by position PhD production by tenured professor per year
Sponsored research	Sponsored research volume Sources of funds (grants vs. contracts) Number of contracts and grants per principal investigator Funds by university and discipline Stanford's share of total federal research funding Stanford's success rates on research proposals
Departmental data	Number of freshmen and sophomore undergraduates accepted Percentage of undergraduate courses taught by other than on-line tenured faculty Number of undergraduate completing degrees Undergraduate production by tenured professor and by other teachers
University	Sources of funds Overhead collected by university

[a] Source: Stanford University (1995).

5. Conclusion

Evolutionary economics has sometimes been criticized for being somewhat descriptive—contrary to neoclassical economics—for not being enough policy-oriented, and for lacking specific applications (Krugman, 1999). However, evolutionary economics and management have the necessary conceptual and methodological tools to include policy dimensions. In the case of the NSIs, which is centrally composed by institutions, a central concept is the idea that institutions are not neutral and that they show different missions and efficiency levels.

The concept of national system of innovation is the key to explaining the behavior and the performance of the set of institutions on which long-term economic growth and sustainable development are based. But in order to help orient not only analysis, but also policy and managerial action in both public and private organizations, it has to incorporate new conceptual and statistical elements. The definitive recognition of the x-efficiency of NSIs institutions, and the adoption of benchmarking as a tool, may help it to go beyond description towards a more policy- and management-oriented evolutionary approach to SIs. At the basis of both inefficiency and ineffectiveness one can probably find the weight of past decisions, path-dependent results of organizational and technological trajectories stemming from localized learning and initial conditions (Foray, 1997).

Benchmarking is already used in private organizations, and it has already started to be used in public ones. It consists in the building of indicators of efficiency and effectiveness in order to find out better organizational routines and facilitate organizational learning. The recognition of national or regional differences (both at the institutions and system levels) should not preclude systematic benchmarking of both organizations and SIs. Benchmarking is not conducted with an aim to reveal optimal performances, but to expose best practices in public, quasi-public and private organizations, thus adding a public policy and management dimension to the evolutionary analysis of NSIs.

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