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Representación de los elementos de un Sistema Nacional de Innovación mediante el Modelo de Sistema Sustentable

Representation of the elements of a National Innovation System through the Viable Systems Model

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Resumen

Este artículo profundiza el análisis realizado en trabajos anteriores relacionados con el establecimiento de un sistema nacional de inteligencia competitiva y tecnológica. En el artículo se sugiere una estructura sistémica y teórica que constituyen la fundación de dicho sistema nacional. Desarrollando una adaptación del conocido modelo de Sistema Viable el cual es un buen punto de partida para la estructuración de los sistemas de innovación e inteligencia competitiva y tecnológica en diferentes niveles de agregación.

Palabras clave: Enfoque sistémico; inteligencia competitiva y tecnológica; innovación; sistema nacional de innovación.

Abstract

This article deepens the analysis of previous works concerning the building of national systems of competitive technical intelligence. We suggest a theoretical systemic framework to constitute the foundations of such national systems. By using an adaptation of the so called Viable System model, the proposed model is a good starting point for the structuring of innovation and competitive technical intelligence systems at different levels of aggregation.

Key words: Systems approach; Competitive Technical Intelligence; Innovation System.

Introduction

In previous works [1][2], the structuring of a national system of competitive technical intelligence (CTI) has been suggested. This is defined as the set of agents and their interactions, participating at the national level in the process of transforming information into strategic knowledge through the operation of a virtuous cycle of intelligence. Among these agents we can mention governmental organizations, research and higher education institutions, support organizations, firms and professional and entrepreneurial associations. In the present work we will deepen our analysis to suggest some ideas for the elements of such a system, with special emphasis on the functional organization of the subsystems and the agents that constitute it.

Our proposal should not be considered to have a prescriptive character, but only as an attempt to provide some orientation concerning the understanding of the basic functions of organizations. Additionally, since we shall be using elements of the systems approach it is worthwhile noticing that we will not attempt to provide a model as a faithful representation of reality, but only as a methodological approach to understand the real world and be able to modify it. For this reason we shall use in our analysis relatively simple, but not inaccurate, systems models, recognizing the fact that the use of complex systems could provide more accurate -but operatively useless- representations of reality. Given its influence on diverse areas of innovation studies we shall start our analysis with a brief account of the use of systems concepts in this sphere.

Competitive Technical Intelligence

Competitive technical intelligence deals with the process of handling general information about the external competitive atmosphere of the business and is also concerned with the associated scientific and technological events of research, development and innovation processes; technological acquisition policies, joint venture, portfolios of R&D, etc. [3][4]. Competitive technical intelligence emphasises on the R&D functions of an organization and also encompasses other activities associated to technology development, such as strategic planning, technology acquisition and process equipment investment among others [5]. A more recent approach states that it helps your company sustain and develop distinct competitive advantages by using the entire organization and its networks to develop actionable insights about the environment (customers, competitors, regulations, technology) by using a systematic and ethical process involving, planning, collection, analysis, communication and management [6][7]. Once this information is developed into knowledge, organizations are able to create strategic plans according to their internal and external changes. Competitive technical intelligence influences a wide range of decision-making areas and is a vital ingredient in the formulation of business strategy [8]. These characteristics make the practice of competitive intelligence relevant to any organization beyond companies.

Using diverse tools of competitive technical intelligence, it's possible to identify the company's behaviour or technological areas in a field and a period of time to determine opportunities and threats for innovation [9][5][4]. Diverse screening efforts, such as scanning (broad surveying of external environment), monitoring (routine, focused tracking of specific S&T topics of interest) and scouting (collecting and screening information on particular technologies, experts or organizations) [5] help organizations accomplish their strategic planning and their specific goals or objectives.

There is a wide variety of organizations, businesses and institutions to which competitive technical intelligence provides opportunities for innovation. The interaction of these varied actors signals an interrelationship between their actions. It is relevant, therefore, to suggest the creation of a national system of competitive technical intelligence in which the synergies of each building block are created for and contribute to the advancement of the system as a whole, in terms of innovation. However, it is necessary to lay the theoretical framework that depicts in a valid way the activities and relationships related to innovation and competitive technical intelligence.

The notion of systems in the literature of innovation

Systems concepts have been broadly used in innovation studies, particularly since the publication of diverse and heterogeneous works using the concept of national system of innovation [10][11][12]. These have stressed the need to use a holistic approach to address the study of the production and diffusion of economically useful knowledge and suggest a general framework consisting in the decomposition of the economic system into the elements and interactions that constitute an innovation processes. Etzkowitz and Leydesdorff's Triple Helix design for a national system of innovation generates a knowledge infrastructure with each of the institutions taking the role of the other [13]. This national system of innovation has been developed taking into account the changes in the environment and the institutions.

Despite having some theoretical problems, such as theoretical diffuseness [14][15], the framework has had a surprising diffusion and some of its aspects have been either adopted by innumerable scholars, policy analysts politicians and international organisations, or adapted as departing point for similar approaches such as sectorial and regional systems of innovation and technological systems [16][17][18]. However, given the theoretical ambiguity of the notion this diffusion has implied different interpretations. The four definitions of innovation systems mostly used have been national, regional, sectorial and technological. Still, these perspectives could be considered to be variants of a generic innovation systems approach that may exist within a given context, yet cooexist and complement each other [15]. However in the past years other concepts at the firm level have emerged in literature [19]. In what follows we will briefly discuss the origin of the concept of innovation systems and the main subsequent interpretations.

The origin of the use of the notion of systems associated with innovation studies can be found in the evolution of the concept of innovation. Particularly, when interactive models of this process were developed in opposition to the dominant linear view and which implied also the participation of a broad group of agents. Andersen [20] suggests that this association can be found in the works of several scholars related with Christopher Freeman and SPRU.

These interpretations of the innovation process are perhaps more related with notions such as social networks than with systems, since this latter have particular, more complex connotations than the interaction between components. Nevertheless, what is clear is that these early associations between systems and innovation implied the conceptualization of this phenomenon as a non–linear process involving interactivity among actors, feedback loops from market to R&D and reverse, learning processes, and external institutions and actors' involvement [21]. Lundvall elaborates on these dynamic views of innovation, though stressing two distinct foci: the business-systems and the innovation-systems approaches. The first, being a primarily sociological perspective, integrates the learning process into the constantly changing patterns of elements within the system, but takes the institutional setup as a given. The second, on the other hand, considers the feedback effects between the economic and institutional spheres, but makes no account of the learning processes that take place among and within the actors [11]. Thus, though varying in their conceptualizations, the acknowledgement of an interactive process is evident in the latter systems definitions.

The subsequent use of the notion of systems of innovation, in the late 1980s and early 1990s, involved an extension of the network conceptualisation of the innovation process to include the role of institutions and to a certain extent some aspects of evolutionary economics. This network of relations generates a reflexive subdynamics of intentions, strategies, and projects that adds surplus value by reorganizing and harmonizing continuously the underlying infrastructure in order to achieve at least an approximation of the goals [13]. It has been extensively discussed that there is not a unified notion of systems of innovation, since the main proponents corresponded to different research traditions, where probably the common denominator was Schumpeter. However, apart from the similarities between approaches suggested by Edquist [14][15], it seems that the 'basic original interpretation' was aimed at explaining national patterns of growth and economic development through the analysis of the interactions between the actors and institutions participating in innovation networks. Padmore et al. argue that a system approach accepts that in principle 'everything interacts with everything' but recognizes that in practice, some interactions matter more than others [22].

Linked with this primary objective, there was also an implicit or explicit policy orientation that is more clearly stated in the Lundvall-Aalborg version in terms of 'institutional learning' [23]. It could be said that this original interpretation was some sort of 'appreciative' evolutionary framework to explain national innovative performance. The main structure of the framework consisted of actors, institutions and relationships involved in innovation activities and from this probably followed the association that it was possible to refer to specific, national innovation systems, i.e. elements and interactions constituting systems at the national level. Lundvall et al. consequently highlight the need for a broader concept of innovation system when speaking of national development analysis. They argue that innovation activities may be equally rooted in firms as in the capabilities of ordinary people within a context where innovation depends on the economic, political and social infrastructures and institutions [23]. This approach has been particularly meaningful for understanding innovation systems for developing countries of the Southern Hemisphere.

Despite the policy orientation, none of the original approaches included an operational version of the systems of innovation approach. This has been mainly developed by the OECD, which adopted the notion since the late 1980s [24][25]. From this followed what can be called the 'generalised interpretation' of the systems of innovation approach. This generalised interpretation has been refined in several OECD reports [26][27][28] as well as in studies carried out by other international organisations such as those of the European Union [29][30] and is usually the one used in the plethora of studies published in the literature that refer to innovation systems.

While the original and the generalised interpretations seem to be very similar, their differences lie in their diverging orientations to use the systems of innovation approach as a theoretical structure to make detailed case studies of economic systems. Thus, each of these systems reveals a particular set of relations of three interlocking dynamics: institutional transformations, evolutionary mechanisms, and the new role of the university [13].

The existence of these interpretations suggests therefore, that an in–depth analysis of the systems of innovation framework from the systems theory point of view could be useful to suggest a unified perspective. However, in what follows, we will suggest an alternative approach based on systems thinking, to the use of the notion of systems in the field of innovation and competitive technical intelligence.

Basic background for a systems approach to innovation and competitive technical intelligence

In order to use the systems approach as a means to understand the decision–making processes that take place within the elements of innovation, such as firms, we will make a distinction between the set of measures intended to modify processes (decision making) and the actual processes themselves. The perspective that we shall adopt in this work corresponds to the point of view of an analyst who is observing economic activities and is interested in modifying certain components and processes to achieve specific goals. First, it is necessary, at least, to specify the type of system we are dealing with (taxonomic considerations); and, subsequently it is necessary to adopt a suitable definition of system consistent with and useful for the type of system under study.

Our first assumption is that firms' decision–making activities, in which we are interested, constitute a subset of reality that interacts with another subset consisting of economic phenomena, the activities in this interaction involving competitive intelligence actions to observe and to modify the processes that take place within the economic subset. To do this, these activities resort to simplified representations or models of what is happening in the subset it observes, as means to reduce the complexity of the observed reality, as well as several types of mechanisms or tools of observation and transformation, which are inextricably linked to the former.

At first sight it seems that the type of situation we are describing could be treated from the systems perspective, firstly, because it resembles conditions that seem to coincide with a commonsensical notion of systems. Secondly, because this same notion makes us believe that the systems perspective is useful to deal with complex problems, and this one, though simply stated, appears to involve high levels of complexity. Thus, our second assumption is that we can analyse decision-making problems from the systems approach. However, this is in fact a broad interdisciplinary area that involves philosophy and natural sciences to engineering and social sciences. Therefore, it will be also important to specify from which area of the systems approach we are going to analyse policy–making activities.

Since the systems approach is based on the hypothesis that it is insightful to consider the apparently chaotic real world not as a set of unarticulated phenomena but rather as a complex set of interacting entities, it is natural that a number of general attempts to describe and classify the possible types of systems have been made. For example, we can find in the literature system's classifications based only on behavioural characteristics [31], and several attempts to define taxonomic principles or general classifications of all possible systems [32][33][34][35][36].

For our purposes, we think that from the above literature, Checkland's classification is sufficient and useful. This is based on the origin of the entities that can be observed in the real world and suggests that any entity which an observer perceives may be described as a system or as a combination of systems selected from the following five classes: natural, designed physical, designed abstract, human activity and transcendental systems. According to this classification, social systems, defined very generally as groupings of people who are aware of and acknowledge their membership of the group, are considered as an intersection between natural systems and human activity systems.

Additionally, and most importantly, human activity systems include an account of the observer and the point of view from which his or her observations are made. From this follows that human activity systems *do not actually exist*, they are perceptions of sets of self–conscious activities made by specific observers from particular perspectives. Thus, the crucial difference which distinguishes this from some other systems approaches rests on the use of the term system and its implications, i.e. what is systemic is not the complex real world, but the process of inquiry that is used to explore reality. Consequently, the models derived from this perspective are not attempts to model the world, but epistemological devices used to understand reality and to contribute to the debate about possible change. From the above discussion it follows that our third assumption is that firms' decision–making activities as well as the parts of the economic system with which they interact are human activity systems.

The next aspect to analyse concerns how to characterise and define human activity systems. In this case it seems more appropriate to concentrate on a subclass of them, and assume that that these types of systems are examples of purposeful or teleological entities, i.e. "things some of whose properties are functional" [37]. We are suggesting then, that firms' decision-making and its interactions with part of the economic system can be interpreted as constituting a purposeful system.

Viable systems model

Churchman's conceptualization gives an account of the necessary minimum elements to design a purposeful system, i.e. one designed to transform reality, in this case a set of decisions to modify firms' internal and external processes. However, we still need a systemic representation of the part of reality within which it operates, that is, the firm itself; to accomplish this, we suggest adopting some elements of the 'viable system model' [38][39][40]. This is based on the application of concepts from neurophysiology and cybernetics to the understanding of the functional structure of systems. It is a general recursive model containing the sufficient functional elements and structure that any system needs to be viable, i.e. able to maintain a separate existence. The recursiveness of the model implies that one of the functional elements contains a copy of the whole system, generating a series of nested subsystems, all with the same structure. Therefore, the basic structure of the model is able to map and represent any complex system. For example, in our area of interest, we can start the analysis at the level of a firm -a viable system itself, which is part of an industry, which in turn belongs to a region within a national economy.

Any system that is capable of maintaining its identity independently of other systems within a shared environment performs two fundamental functions: current and long–term stabilisation. These are carried out by two composite subsystems —the system and the metasystem, that operate in different dimensions of recursion and perform five sub–functions: (1) production of the whole system itself; (2) regulation or coordination of the diverse productive components; (3) self–awareness of the system's identity and control; (4) intelligence, foresight, innovation and planning; and, (5) establishing policies to guarantee the cohesion of the whole (see figure 1). Given their nature, production and intelligence include an additional function of perception or link with the environment.

The next important characteristic is the network of interactions that connect the functional components. The nature of the relationships is partly defined by the function of the elements and partly by the characteristics imposed by the purpose of the whole system. These interactions imply the flow of information containing encoded variety. In fact, the whole system is an entity whose main task is to deal with complexity by variety engineering. This means that the system faces an environment that presents a vast number of possible states and thus, must be capable of generating an equal number of internal states to absorb the variety of the environment. Consequently, its internal network of interactions corresponds to the flow of different types of resources as well as regulations and coordination rules that allow the production components to respond to the variety of the environment. This entire network is structured and regulated by the law of requisite variety [41][42], which in a simplified form states that only variety absorbs variety.

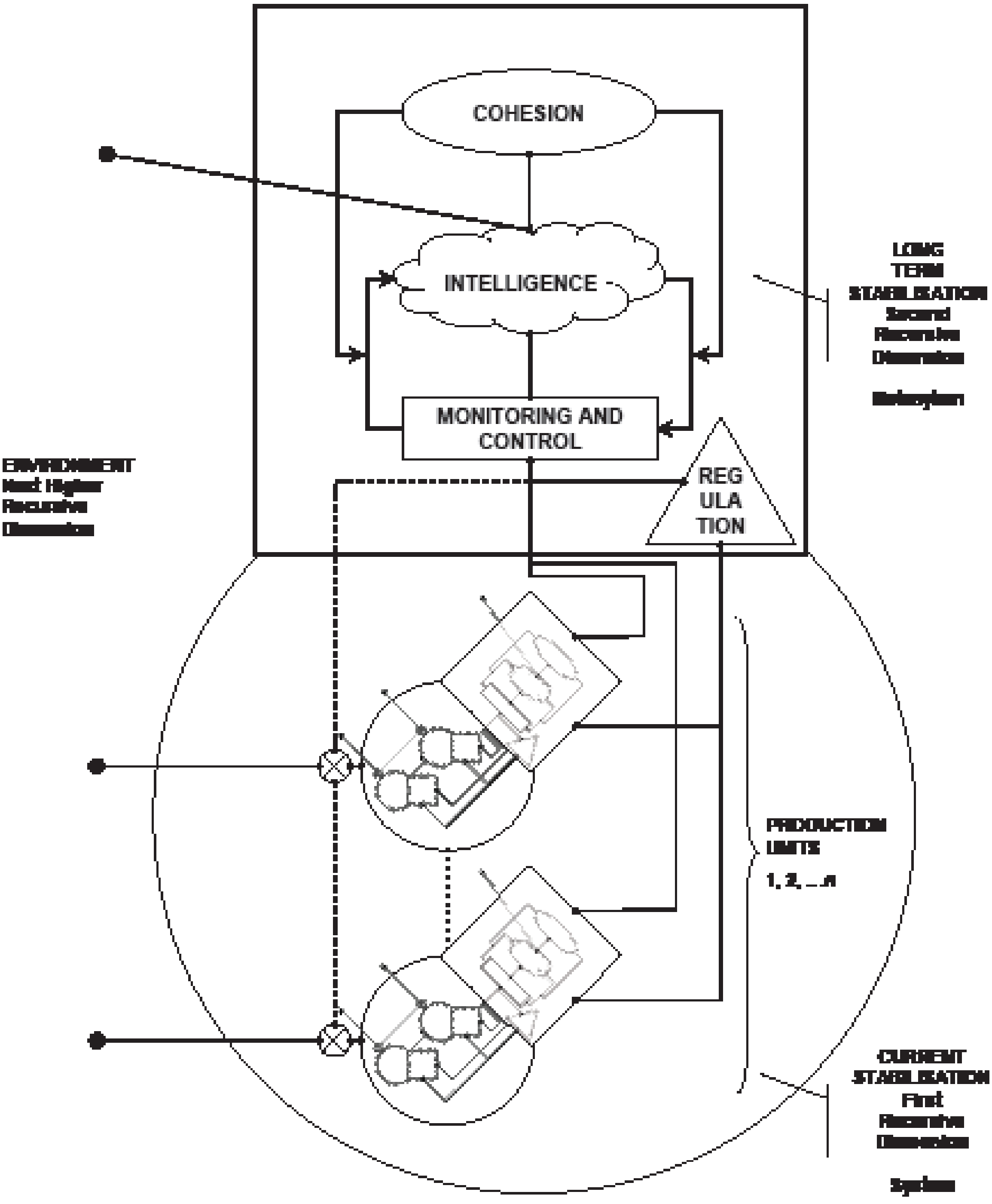

Figure 1. The viable or sustainable system model.

Elements of the innovation system as viable systems

Our previous work has utilized the Viable Systems Model to understand the operation of policy-making activities within an economic system [43]. We have chosen this same conceptualisation and structure to solve a problem of the current applications of systems notions to innovation studies. In these, there is a frequent confusion between phenomena occurring in different dimensions. They usually refer to activities that correspond to the interpretation of the actual production system and at the same time to activities that correspond to normative aspects (institutions) related to that production system. Consequently, these interpretations establish a boundary for these components -regions, industrial sectors or nations, but assume that these elements and institutions constitute a system and subsist at the same hierarchical dimension. From this follows an unsolved debate concerning the appropriate location of those boundaries.

The aspect that is missing from these interpretations is that these elements and institutions constitute a purposeful, sustainable, composite and multidimensional system. In it, the production activities occur in a basic dimension and the policy, intelligence, control and regulation functions take place at a higher level dimension, though control and regulation are inter-dimensional -the system and the metasystem. However, this composite system constitutes a unity with an internal environment and simultaneously, given the recursive nature of the model, its metasystem is an element (a new production unit or system) of another unity subsisting at a higher dimension of recursion (see Figures 1 and 2). The latter describes the task of the competitive intelligence effort, in which the firm's activities are linked to a higher level of aggregation – an environment in which the described system is contained. Therefore, we establish the direct link between the metasystem and the competitive intelligence task in the viable system representation.

The advantage of this model is that it provides a coherent account of how basic units, which are viable systems themselves, are interlinked and nested to constitute higher levels of aggregation in each recursion through the metasystem [44]. Systems differentiate in a self–referential process of distinguishing themselves from the environment and simultaneously organising in subsystems with an internal structure that reproduces the structure of that environment. Such a conceptualisation is much closer to reflect the actual systemic nature of industrial processes, since it is now possible to map how individual firms constitute industries, a productive sector and subsequently a national economy.

We are suggesting thus, that any element in the innovation system —a nation, an industry, a cluster, a firm, etc., can be represented as a viable system which performs the referred five sub–functions in every dimension of recursion. Naturally, this functional description can adopt quite different organisational structures in each particular case. The detailed mapping of economies as viable systems is out of the scope of this work and we shall refer only to the

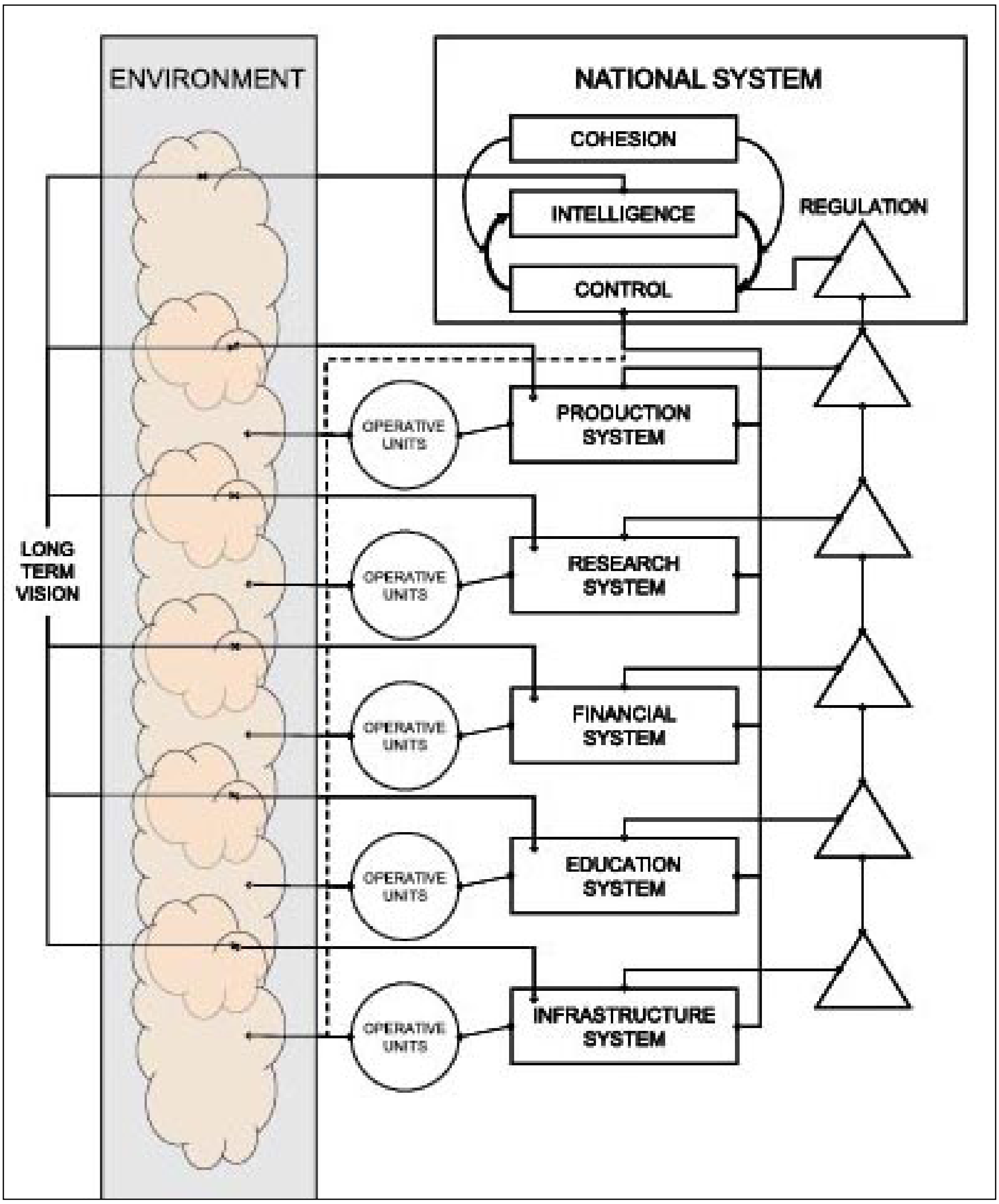

Figure 2. A sustainable national system of production.

more general aspects related to our purposes. Nevertheless, Figure 2 depicts a possible general structure for a national system.

The subsystem that we have called intelligence, corresponding to the concept of competitive technical intelligence, is multifunctional, since it includes, at firm level for example, foresight, strategic planning and R&D. We have used the term intelligence, since it is closer to represent a purposeful perception of the environment and the consequent actions to shape the future of the firm.

At one of the higher levels of aggregation, let us say at the national level, the innovation system is composed of several subsystems or production units which are responsible of the reproduction of the whole system itself. From our perspective, these can be understood as producers of knowledge, either codified or embedded in products, processes or services. In a higher recursive dimension, several other organisations constitute the subsystems that are in charge of self–awareness and control, coordination, intelligence and cohesion. We must remember that in each recursion we will find that the same functional structure is repeated, since they are also constituted of sets of viable systems. Therefore, a firm, which could be usually considered the lowest dimension of recursion in an innovation system, is also composed of viable systems and has components that perform the functions of production, coordination, control, intelligence and cohesion.

Let us attempt to describe briefly how these subsystems interact in the case of a firm. The best place to start is with the production subsystem, i.e. what we have called 'the system'. The purpose of this is to generate the products or services that satisfy particular demands of the market. It also performs diverse operational and managerial activities to achieve its purpose. These are determined on the one hand, by the variety of the market situation, including demand, supliers, competition, and market demand. The other set of constraints are imposed by the resources and capabilities of the whole firm as well as by a series of regulations established internally, such as procedures, and externally —by systems at higher recursive dimensions, such as new available technology, shifting business models, and norms. As Devine proposes, by focusing on the variety of the external environment, the Viable Systems Model gives a framework to address the system's needs for variety [45]. There can be several production subsystems within a firm, each one of them attending different market demands. The crucial aspect of this scheme is that each production unit has to cope with a particular level of market variety and be capable of generating the sufficient variety —products or services within specific ranges of qualities (prices, performance characteristics, etc.) to absorb the market demand.

As mentioned above, the subsystem of regulation constrains the production subsystems according to internal norms, rules, and practices that aid in the coordination among several similar units. Additionally, it transmits the constraints imposed by higher–level systems in the environment. This regulation subsystem is in close operation with the control subsystem whose functions include the mechanisms to allow awareness of the internal state (of the production units) through audits or evaluations, and the mechanisms to distribute the flow of resources (human, physical, financial and knowledge).

To be able to control the intelligence process, this subsystem needs a permanent exchange with the intelligence subsystem responsible of surveying the environment, making the relevant plans and performing the consequent innovation activities. The latter essentially supplies knowledge embedded in the vision of the future of the organisation —which is basically established by determining the necessary adjustments of the variety response of the firm to cope with future demands and the threats of competition, as well as in all the intangible assets that the operational units require to adjust their outputs. Finally, the system that closes the loop is in charge of establishing general policies that give cohesion to the whole. Salo suggests that the process of foresight, as it aims for the longer-term economical and social benefits, improves coordination among the visions, intentions, and actions of all involved stakeholders [46]. To do this, its main task consists of monitoring and balancing the forces and the flow of information and variety between the subsystems of control and foresight, setting the system in a permanent process of learning and adaptation. Thus, it seems paradoxical, yet accurate, that the whole system is a complex entity to destroy variety, since it generates variety through its internal processes.

Conclusion

We have suggested a general systemic framework as a methodological tool to understand activities related to innovation and competitive technical intelligence. With them, thanks to the characteristics of systems, we have been able to recursively describe some aspects of the operation of an innovation process. From this perspective, it is possible to solve some of the theoretical and operational problems of traditional systems of innovation perspectives. Firstly, we are suggesting a model that is consistent with the systems approach and is based in the identification of processes or functions, which can be generalised to any system within the established boundaries.

Secondly, our proposal does not attempt to explain economic phenomena in holistic terms, but through the detailed analysis of a series of recursive and sustainable subsystems. It is precisely this nature which allows the model to be applied in different levels of aggregation according to the interests of study; sector, regional, national, etc. Additionally, these aspects also imply that the system used to model reality is not simply constituted by a set of elements and interactions, but by functional subsystems hierarchically organised, that are increasingly more complex according to the level of aggregation of the analysis.

Finally, our viewpoint makes explicit the duality that emerges while approaching this phenomena from the systems perspective, since we are distinguishing between the observed reality, which is perceived as a system to reduce its complexity —what we have called the 'system'; and the observer that designs and implements mechanisms to transform reality —which has been referred as the 'metasystem'. As we have seen, both form part of the same sustainable system, at different levels of recursion.

The building of a national system of competitive technical intelligence should start at the level of individual organizations, through the constitution of the minimum units of organization, firms, research centres, public support organizations, as sustainable systems. Only in this way, the emergence of higher hierarchy dimensions will be possible. In the last instance these will constitute industrial and research subsystems as the basis for sustainable productive systems at sector, regional or national levels.

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