An Approach to the Measurement of Technological Change Based on the Intensity of Innovation

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Abstract. The economics of innovation presents a lot of taxonomies of innovation. This research introduces the scale of innovative intensity (SIIN) based on a meta-taxonomy that subsume other, less comprehensive taxonomy. The SIIN is similar to the seismic scale of Mercalli used for measuring the intensity of earthquakes. This scale is used for a theoretical framework of measurement based on the economic impact of the technological innovation on the economic system. The theory is applied on some case studies from agricultural mechanisation and ICT industries and the results show as the Internet innovation has a higher economic impact than farm tractors.

Keywords: Technometrics**,** Technological Change, Innovation Intensity, Economic Impact, Innovation Waves, Innovation Patterns

Jel Classification: D00, L20, O10, O30, O33

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Introduction

The definition of technical progress as an advance in the production function purely due to the effects of the technical developments is inadequate. Majer (1985) defined the technical progress as: the appearance of new, improved products; the introduction of new or improved production processes which make it possible to produce the same output with less input and finally, the development and use of new means to satisfy human needs. Ayres (1985) states that scientists and engineers consider "technological change" to be limited to research and development, innovation (the introduction of new products and processes) and the improvement of existing products and processes.

Technological change occurs on the basis of three phases: genesis, normal technical progress and technological frontier. In the first phase a series of potential technological paradigms are generated and after that, the so-called *focusing devices* (Sahal, 1981) select the former on the basis of ex-ante (economic) and ex-post (market) elements and give rise to the dominant technological paradigm (model and a pattern of solution of selected solutions technological problems, based on selected principles derived from the natural sciences and on selected material technologies; Dosi, 1982). During the phase of "normal technical progress", technological trajectories (the activity of technological process along the economic and technological trade-offs defined by a paradigm; Nelson and Winter, 1982) are generated and they show the constant flow of technological change. The third phase represents the maximum level reached during a technological change.

The technological change assumes, in the present scenario of globalisation, fundamental importance for various fields, amongst which R&D management of public and private labs, Research and Economic policy, technological transfer and so on. In the field of research policy a central problem in the formulation of a national research strategy lies in the choice of appropriate technology within a given field. Public support for the development of a specific method could be based on scrupulous assessment of future results. Therefore the measurement of technological change is essential for correct management practices. As part of the economic policy certain explicit measures of technological change have important implications for the measurement of economic growth, studies into consumer behaviour, analysis of international trade and evaluation of monetary and fiscal policies. Technology is the key to forecasting and management of new product and process innovations. The measurement of technological change, and its interpretation, remain one of the most difficult problems for scholars to analyse, due to the many variables involved. Souder and Shrivastrava (1985) said "we can't begin to make decisions about technology until we understand it. And we can't begin to really understand it until we can measure it".

This paper attempts to answer the two following questions, which are fundamental to technometrics. The first question we posed was whether it was possible to create a taxonomy of technological change that synthesises the numerous denominations of innovation existing in economic literature in a more simple manner, based on the various characteristics of each type of innovation and the effects it generates within the geo-economic environment. After identifying this common denominator, a further query was whether it was possible to classify the intensity of these innovations according to a scale of increasing value, in order to demonstrate the power of certain innovations and the respective economic impact. Both these queries are centred on the approach of the measurement of technological change dubbed 'seismic', since it aims to construct a scale of evaluation of technological change similar to that used in seismology by Mercalli-Cancani-Sieberg to evaluate the intensity of earthquakes through the description of the effects on the geographical landscape. In fact, according to this approach the economic landscape is changed by waves of innovative impact that modify the environment with a series of effects both on the infrastructures and market, and on the behaviour of the adopters. The idea that 'S' shaped innovative waves traverses the economic landscape can also be found in the work of Sahal (1985) when he describes the evolution of certain technologies.

This metrics that evaluates the economic and social impact of technological innovation attempts to estimate the intensity over time and space, since the effects of technological change vary according to the spatial situation in which the innovations spread and the point in the evolutionary cycle at which they occur. This work is presented in two parts: the first concerns the taxonomy of technological change (sections 2 and 3), the second focuses the measurement of technological change (sections 4, 5, 6).

1. Innovation Taxonomies in Economics and Management

Durand (1992) lists the various points of view used for analysing innovation: a) *Technology*: innovation can been seen through its technical content or through the requirements it put to the firm's capabilities; b) *Market*: innovation can be assessed through the consumer's perception or through the impact that it may have on the dynamics of competition.

Four different perspectives can be adopted to analyse the intensity and the significance of technological change: 1) *Technological input:* technical novelty or scientific merit; 2) *Competence throughput:* new requirements on the competencies (resources, skills and knowledge), *transilience* (Abernathy and Utterback, 1985); 3) *Perception of the market*: market novelty, new functions proposed to customers; 4) *Strategic output*: impact on the competitive position of the firms.

Afterwards Schumpeter (1939), according to whom technical knowledge is acquired both through inventions and innovation, the economists identified within the technological change several kinds of innovations: improvement and fundamental (Mensch, 1979); incremental and intermediate (Priest and Hill, 1980); mild and major (Archibugi, Santarelli, 1989). Other researchers (Durand, 1992) evaluated the impact of innovation on the competition by revisiting the technological dominance of Abernathy and Utterback (1985), the technological paradigms of Dosi (1982) and the hierarchical diagrams of Clark (1985). Freeman (1984) proposed taxonomy of innovation on the basis of economic criteria. Sahal (1985) e Saviotti (1988) made numerous attempts to analyse innovation on the basis of their technical-engineering importance. The latter is less suitable for evaluating the impact of technological change on the entire economic system. Pavitt (1984) classified innovation according to the subjects that generated it, identifying four sectorial taxonomies (science based, specialized supplier, scale intensive and supplier dominated).

Garcia and Calantone (2002) sustain that innovations are frequently classified in taxonomies to identify their innovative characteristics and the degree of innovativeness involved. In literature the following classifications are used above all in the product innovations:

- eight categories – reformulated, new parts, remarchandising, new improvements, new products, new users, new customers (Johnson and Jones, 1957);
- five categories – systematic, major, minor, incremental, unrecorded (Freeman, 1994);
- tetra categorization – incremental, modular, architectural, radical (Henderson and Clark, 1990); niche creation, architectural, regular, revolutionary (Abernathy and Clark, 1985); incremental, evolutionary market, evolutionary technical, radical (Moriarty and Kosnik, 1990); incremental, market breakthrough, technological breakthrough, radical (Chandy and Tellis, 2000); incremental, architectural, fusion, breakthrough (Tidd, 1995);
- triadic categorization - low, moderate, high innovateveness (Kleinschmidt and Cooper, 1991); incremental, new generation, radically new (Wheelwright and Clark, 1992);
- dichotomous categorization – discontinuous, continuos (Anderson and Tushman, 1990; Robertson, 1967); instrumental, ultimate (Grossman, 1970); variations, reorientation (Norman, 1971); true, adoption (Maidique and Zirger, 1984); original, reformulated (Yoon and Lilien, 1985); innovations, reinnovations (Rothwell and Gardinier, 1988); radical, routine (Meyers and Tucker, 1989); evolutionary, revolutionary (Utterback, 1996); substaining, disruptive (Christensen, 1997); really new, incremental (Schmidt and Calantone, 1998; Song et al., 1998); breakthrough, incremental (Rice et al., 1998), radical, incremental (Balachandra and Friar, 1997; Freeman, 1994).

The measurements used in the empirical studies to classify the innovations are divided into two main areas: 1) at macro level, the characteristics of the innovation that are new to the world, market or sector are considered (Maidique and Zirger, 1984; Lee and Na, 1994). The innovativeness is evaluated on the basis of factors exogenous to the company, such as the familiarity of an innovation to the world and industry or the creation of new competitors due to the introduction of the new innovations; 2) at micro level, the innovation is new to companies or to the consumer (More, 1982). Some researchers use both yardsticks (Ali et al. 1995; Cooper, 1979; Cooper and de Brentani, 1991).

Technological innovation has two forces from which discontinuity may originate, in fact the product innovations are often characterised as radicals versus incrementals and market pull versus technology push (Darroch and Jardine, 2002). Dosi (1988) states that an incremental innovation is more probable than a market pull innovation, while a radical innovation is generally originated by scientists and often incorporates new technologies or new combinations of existing technologies. Thus, radical innovation is often classified as a technology push innovation (Cooper, 1979; Green et al., 1995; O'Connor, 1998).

Garcia and Calantone (2002) use the above levels (macro versus micro, marketing versus technology perspectives), taken from literature on marketing and engineering, and apply Boolean logic to unequivocally identify three labels for innovations: radical, really new and incremental. The radical innovations are those which cause discontinuity of marketing and technologies, both at a macro and a micro level. Incremental innovations occur only at micro level and cause either discontinuity of marketing, or discontinuity of technology, but not both. Really new innovation covers combinations of these two extremes. These three denominations are appropriate classification that show a reduction in the degree of innovativeness (radical → really → new incremental). Garcia and Calantone (2002) emphasise that the innovativeness of the products must be evaluated on two levels: micro and macro and discontinuity of marketing/technology. Moreover at macro level, the discontinuities are exogenous to the companies, while both macro and micro level, the greater the innovativeness as far as discontinuity of marketing/technology is concerned, the greater the impact on the innovative products. If the discontinuity of the market or of the technology is low, the product will have a low level of innovativeness.

The profusion of types mentioned means that different types of innovation are called by the same name and the same innovation is classified in different ways. Garcia and Calantone (2002) mention some examples such as the typewriter and the Canon laser photocopier to show that the same innovation can be placed at the beginning or the end of the scale, according to the researcher. The ambiguity of this classification makes it impossible to compare the various studies and, according to the authors, the numerous denominations existing in literature for product innovation, have hindered the development of knowledge in these fields.

2. Scale of innovative intensity: a gauge for the intensity of technological change

The first question we considered was whether it was possible to synthesise the numerous denominations for innovation that exist in economic literature on technological change in a simpler and more univocal manner, based on the various characteristics of each type of innovation and the effects generated in the geo-economic system.

Some economists (Kleinknecht, 1990; Schumpter, 1939; Mensch, 1979) showed as the economic systems are affect throughout their evolutionary progress to what have been called innovative waves that can be similar to the propagation of seismic waves in the Earth (Coccia, 2002). In order to go beyond heuristic analogies, it is necessary to develop ways to measures of the state of innovation in economic systems and to provide assessments of the effects on the economic environment. At present in Economics of Innovation there are not measurements for the effects of innovation on the environment, although in other fields there are many different scales used for classifying (and quantifying) an event or the power of a change. Amongst the most common examples is the MCS scale (Mercalli, 1883; Cancani, 1903; Sieberg, 1930) or the Richter scale (1958) used in geophysics to measure the intensity of earthquakes, the international scale of nuclear events (INES), the scale invented by the English admiral Beaufort for indicating the force of the wind and the Douglas scale for indicating the state of the sea.

Evaluation of the innovative intensity has always interested the economists who have used various criteria to classify the technology change. Inside the economic system several types of innovation may occur, some only slight, others greater, some slow to spread, others more rapid. A simple description of the type of innovation may be useful, but at the same time it ignores main information. In order to better study the technological change it is necessary to begin by identifying the principal elements that influence the spread of innovation and that can be synthesised as follows:

- endogenous to the innovation. Sahal (1985) states that innovation undergoes, during diffusion, changes due to its functional and structural properties;
- environmental, linked to the economic conditions in which the innovation is spread (distance of the users from the source, route, industrial system, and so on);
- social, depending on the cultural level of the population that receives the innovative event.

We attempted to answer the question we posed at the beginning of the research by constructing a scale, called Scale of Innovation Intensity (SIIN), that evaluates the economic impact of the technological innovation by simply describing the effects on the environment, in a similar manner to the field of seismology with the Mercalli Scale[1] which empirically evaluates the intensity of earthquakes according to the effects on the landscape of the seismic waves. Although the SIIN is qualitative/ordinal, it was considered opportune to successively construct a system of measurement through a formalisation of the degree of innovation intensity in order to logically analyse the economic impact of the technological innovation on the system. Before dealing with this problem it is necessary to consider the following definition:

DEFINITION 1. The scale of innovation intensity (SIIN) is an increasing classification of the intensity of the technological change according to the effects produced by innovation on the socio-economic system.

The creation of a common denominator for the various types of innovation is designed to systemise technological change on a scale with a universal application. The SIIN is centred on the concept of *intensity*, which distinguishes the innovations on the basis of the number of adopters and/or elements affected by the innovation (consumers, companies, infrastructures, markets, sectors, etc.) and the effects (changes) on the geo-economic environment. The sensors that can be used are:

- *Number of users*
- *Changes in means of communication*
- *Changes in the markets, in the means of communication and the socio-economic environment*
- *Increase in the level of welfare and in the individual and social utility*

Table 1 - Scale of innovative intensity

Innovation degree		*Level*	*Intensity*
1st group	I = 1°	Low	Lightest
	II = 2°		Mild
	III = 3°		Moderate
2nd group	IV = 4°	Medium	Intermediate
	V = 5°		Strong
3rd group	VI = 6°	High	Very strong
	VII = 7°		Revolutionary

The scale of innovative intensity is described in table 1, while table 2 is more detailed and shows some of the numerous taxonomies for innovation that exist in literature and which are synthesised in new levels, the number of users involved and the description of the principal effects produced of the innovation waves in the economic environment. The number of degrees has been defined as equal to seven since the degrees that best synthesise the types of technological innovation existing in literature were found to be seven. It must be noted how innovative intensity, *at a spatial level*, is greatest in the areas where the innovation is born (place of birth) and has a high adoption (called innovative epicentre), also for the circulation of the so-called localised knowledge (Antonelli, 1995; 2000) and reduces the level as its adoption decreases. In fact, the reduction in intensity is characterised by the reduction in the effects/changes in the environment, which in some cases depend on the distance of the innovative epicentre (Hägerstrand, 1960), the environmental receptiveness (culture, means of communication, etc.) and the rank of the city. *At a temporal level*, the intensity reaches a peak when it spreads in a wave (or curve) of greater amplitude (height) and period (length) than others. Examples are to be found in Sahal (1985).

1 The reference to the academic Mercalli is justified by the fact that he was the first, in 1902, to propose a scale of seismic intensity, perfecting the concept introduced in 1880 by Michele De Rossi and François Forel, later integrated by the Americans Wood and Neumann. Further integration was made by Cancani and Sieberg and this explains the present denomination in Western Europe of MCS scale, in honour of the three great seismologists. Similarly in Eastern Europe the MKS scale is used (Medvedv, Karnik and Sponheuer).

Table 2 - Taxonomy of technological change: the scale of innovative intensity

EFFECTS OF TECHNOLOGICAL CHANGE					
Degree		*Intensity*	*Some denominations of innovations used in literature*	*Number of adopters/ products involved*	*Decryption*
I GROUP: Low Impact	I	Lightest	Elementary or micro-incremental (Coccia, 2002) Unrecorded (Freeman, 1994)	Isolated individuals	Generally concern only certain subjects. There are only marginal changes with respect to the overall system. Productivity and sales of firms are not increased. ▪ **Principal effect**: increase in marginal utility of product
	II	Mild	Incremental (Freeman et al. 1982; Priest e Hill, 1980) Market Pull (Dosi, 1988) Normal science (Khun, 1962) Regular (Abernathy e Clark, 1985) Continuos (Freeman et al., 1982) Minor (Archibugi e Santarelli, 1989) Improvements (Mensch, 1979), etc.	Very few	Minor changes in product and process. Empirical studies show that it is possible to increase productivity. The competition focuses on costs, on the attainment of quality and the strategic differentiation. These innovations occur almost continuously within the economic system. They mainly affect the company that promotes them. **The technological trajectory tends to grow. Geometrically it climbs the curve of diffusion of the innovation coming close to the point of saturation.** ▪ **Principal effect**: increase in productivity
	III	Moderate	Major (Archibugi e Santarelli, 1989; Rycroft e Kash, 2002) Non drastic (Arrow, 1962; Gilbert e Newbery, 1982) Really new (Garcia e Calantone, 2002) Market breakthrough (Chandly and Tellis, 2000) Modular (Henderson and Clark, 1990), etc.	Few	Involves a number of users. Companies alter their production processes and there is a change in the hierarchy of the market share. Geometrically they lie on inflexion point of the curve of diffusion (e.g. logistic function) and give birth to **a new technological trajectory.** ▪ **Principal effect**: considerable increase in productivity
II GROUP: Medium Impact	IV	Intermediate	Micro-radical (Durand, 1992) Evolutionary Technical (Moriarty and Kosnik, 1990) Niche creation (Abernathy e Clark, 1985) Technological breakthrough (Chandly and Tellis, 2000) Non drastic (Arrow, 1962; Gilbert e Newbery, 1982), etc.	Fair	Intermediate improvements in the process of innovation, which can open new links with the market. Many of these innovations generate market niches. Only part of the competence accumulated around previous dominant technology is destroyed. **More than one new technological trajectory is born.** ▪ **Principal effect**: new markets open up, increase in market size and rate of growth of the economic system
	V	Strong	Radical (Freeman et al., 1982) Breakthrough (Tidd, 1995) Technology push (Dosi, 1988) Drastic (Arrow, 1962; Gilbert e Newbery, 1982) Discrete (Priest e Hill, 1980) Fundamental (Mensch, 1979) Discontinuos (Archibugi e Santarelli, 1989) Basic innovation (Mensch, 1979) Architectural (Abernathy e Clark, 1985), etc.	Many	Occur discontinuously over time. This level of intensity changes the production conditions in more than one company. A new product is born. According to Abernathy and Clark, the basic configuration of the product is redefined. New sectors are created and the competitive equilibrium of the companies is altered by the arrival of new companies. This innovation also allows a reduction in the work and the costs; and a considerable increase in the satisfaction of the individual. **A new technological paradigm is born.** ▪ **Principal effect**: a fundamental need is satisfied and a new market is born
III GROUP: High Impact	VI	Very strong	New technological Systems (Freeman et al., 1982) Innovation systems (Sahal, 1981) Constellations of innovations (Keirstead, 1948) Clusters of innovations (Freeman et al., 1982), etc.	Very many	Concerns a cluster of innovations. The inter-sector competition is altered. Has considerable pervasive effects which change the production conditions not only in the sectors (or markets) that produce and use it, but also in linked sectors. The economic impact of the technological innovation improves the present means of communication, the markets are turbulent and the economic system has a considerable development. **The old paradigms reach their frontier and new technological paradigms are born of them.** ▪ **Principal effect**: improves existing means of communication and extends life expectation, change the structure of some markets.
	VII	Revolutionary	Technological revolutions (Freeman et al., 1982; Freeman, 1984) Revolutionary (Abernathy e Clark, 1985) Change of technological paradigms (Dosi, 1982) Change of Techno-economic paradigms (Freeman et al., 1982) Technological regimes (Nelson e Winter, 1982) Cluster of New technological systems (Coccia, 2002), etc.	All	Freeman et al. (1982) quoting Shumpeter (1911; 1939) spoke of ... creative storms... which have profound effects on the economic system and radically change the style of production and management. The introduction of electricity and steam power, or the computer are typical examples of these transformations. Changes of this kind bring with them clusters of innovations, both radical and incremental, which can even give rise to new technological systems. This type of development not only leads to the birth of a new range of products, services, systems and industries in the sector directly involved, but also affects, directly or indirectly, almost every other sector of the economy... The means of human communication are radically changed and a new means of communication that heavily influences all the economic subjects is born, forcing all those who use it to change their habits. **A new techno-economic paradigm is born.** ▪ **Principal effect**: means of communication are changed

Table 3: Example of the intensity of the innovations in agriculture

Innovation degree		**Level**	**Intensity**	**Example**
3rd group	VII = 7°	High	Revolutionary	Steam-driven machinery of J. Watt (≈1775). Let this degree equal to set A
	VI = 6°		Very strong	River navigation by steam boat (1807), *ibidem* B' Steam Locomotive (1813), *ibidem* B'' Steam vehicle with 4 wheels (1802), *ibidem* B''' such that B'; B''; B'''⊂B
2nd group	V = 5°	Medium	Strong	Steam Tractor for farm use (1892), *ibidem* C
	IV = 4°		Intermediate	Gasoline Tractors (1908) *ibidem* D
	III = 3°	Low	Moderate	Low-pressure rubber tires for tractors (1932): Let this the element *a* Hydraulic remote control of drawn implements (1947): ibidem b such that {a, b}=E
	II = 2°		Mild	Dual rear wheels (1965): c Electric remote control of implements (1970): d such that {c, d}=F
	I = 1°		Lightest	Radio car: g such that {g}=G

PROPOSITION 1. Let 7° = set A, 6° = B (such that B', B'', B'''⊂B), 5° = C, 4° = D; 3° = E, 2° = F, 1° = G ⇒ the scale of innovative intensity has the following relations:
B⊂A;C⊂B'''; D⊂C; E⊂D; F⊂E; G⊂F. For the transitive properties also G⊂A.

2.1. Example of application

The following example shows the differing degrees of intensity in a given context; the scale is shown in inverse order for greater clarity (Table 3).

PROOF. If we consider a given good or service (agricultural labour) affected by a revolutionary innovation, over time we will notice that it is characterised by a series of improvements (reduction in the work) of gradually decreasing intensity, with respect to the initial situation (steam-driven machinery) which produced the change. Mathematically this is represented by an 'S'-shaped curve, which shows that the movement dwindles as the potential of the innovation that originated it is absorbed.
In this sense $G \subset A \Leftrightarrow \exists x \in A \mid x \notin G$.

REMARK 1. It must be noted that the above mentioned relations consider an indicator of the benefit (for instance rice in productivity = *x*) created by the innovation on the good (agricultural labour). The use of the theory of sets helps us to understand that there are innovations of differing intensity (and economic impact) and that the innovations of I are small sets and subsets of increasingly large sets (VII innovations). Clearly the car radio shown in the example is a low-grade innovation with respect to the VII that originated it (electronics), but in the example it is simply considered a I degree since in agriculture, compared to the tractor – a technological innovation that allowed a considerable saving in work-hours and increased agricultural yields – it is absolutely marginal, since it contributes to the infinitesimal increase in productivity.

3. Approaches to the measurement of technological change

Over the last thirty years various approaches to the measurement of technological change have been presented. Before describing the seismic approach, which introduces a quantitative metric in support of the grading of the intensity on the SIIN scale, it is considered opportune to rapidly review the history of the most important contributions.

3.1. Hedonic Approach, Court (1939), Stone (1956), Lancaster (1966) and Griliches (1971)

The basic theory behind this approach is that the utility of the product or service lies in its qualitative characteristics, for example in the case of a motor vehicle: the dimensions, the engine power, the fuel saving and so on. The variations in price between the various goods or services can be explained, at moment of time *t*, with the differences in qualitative characteristics. Sahal (1985) highlights the limits, such as the methodology works well only when there are product technologies and distinct features, and it does not work well in the presence of innovations of process – particularly when the price is not set in a market of competition.

3.2. Rand Approach, Dodson (1985) and the contribution of Alexander-Nelson (1973) and Martino (1985) on the trade-off surfaces

The difference between this approach and the previous one is the choice of the dependent variable, which is the price in the Hedonic approach, and the calendar years in the Rand approach. Dodson defines the state of the art (SOA) for a given technological field, as the plane in a bi-dimensional space or the hyper plane in *n*-dimensions, where *n* is the number of characteristics essential to the technology. He proposes two basic surfaces, the planar and the ellipsoidal which mathematically have the following equations:

Ellipsoidal

$$\sum_{i=1}^{n}\left(\frac{x_i}{a_i}\right)^2 = 1$$

Planar

$$\sum_{i=1}^{n}\left(\frac{x_i}{a_i}\right) = 1$$

where x_i = i-th variable (defined along the ith axis) and a_i = constant which is also the zero intercept along the ith axis.

The aim of the Rand method, as Dodson himself explains, is to represent the SOA as a multi-dimensional space and measure the technological change in terms of movement of the surface over time. The limits of this method are: the SOA does not change over time and the rate of technological change is constant throughout time. According to Sahal (1985) the use of only chronological time as a measure of technical progress may lead to the conclusion that Europe in the Middle Ages was more advanced that Archimedes's Greece in 212 B.C.

One contribution to this approach was offered by the improving of the trade-off surfaces. The first contribution of the trade-off surfaces in a bi-dimensional space can be attributed to Knight (1985). Dodson (1985) developed trade-off surfaces in a multidimensional space, stating that they could be convex and selecting the ellipse as the simplest surface that could have the desired characteristics. Alexander and Nelson (1973) developed an alternative procedure using hyper-planes rather than ellipses and applying the method to aircraft turbine engines.

Martino (1985) carried out research into the trade-off surfaces based on Dodson's work but with two variations: a) Dodson limited his surfaces to ellipses of order 2, Martino's extends to ellipses of any order; b) Martino (1985) changed the fitting procedure. He minimized the Mean Asbolute Deviation (MAD) rather than the Mean Square Deviation (MSD). Sharif (1986) considered this procedure too complex.

3.3. The contribution of Saviotti based on the measurement of the hedonic prices (1985)

Saviotti applied two methods for mapping and measuring technological change: 1) use of the method of the principal components; 2) use of the method of hedonic prices. The basic hypothesis of the Saviotti method is that the utility of a product or service lies in its essential qualitative characteristics. His approach is a combination of different methods. First, he gives a description of the characteristics of the products (a given model can be described as a set of characteristics and their value). Secondly, the quality of the product depends (it is a function) on its characteristics, thus defined:

$$Q_j = f(a_1,...,a_n, X_{1j},..., X_{2j},..., X_{kj})$$

where a_i is the relative importance of the i-th characteristic and X_{ij} is the quantitative level of the same characteristic of the model of the product *j*.

After estimating the function with regression techniques, the changes observed are decomposed in an effect of technological/quality change and a pure price effect. The method is illustrated using the technology of the motor car, in a period that covers the UK market from 1955 to 1983.

3.4. Functional and structural approach of Knight (1985)

Knight (1985) states that a functional and structural definition can be used to give a more accurate measurement of technological change. Knight's structural model originates in the work of Burks, Goldstine and von Neumann (1946) who describe the computer hierarchically: the levels of the hierarchy were identified through the degrees to which they specify the characteristics of the computer. The function description of each new computer shows how the technological progress occurred, but in order to accurately describe the details of the new development a structural description is necessary. The development is identified by comparing the structure of a new computer system with the previous one. It is possible to note a series of new elements and improvements in the characteristics of the performance. The result of the structural changes represents the new technology introduced. This method, according to Knight, gives a precise definition of what is and is not a technological change in terms of improved performance.

3.5. Composite approach (Wholistic and Holistic) to the measurements of technological change (Sahal, 1985)

The Sahal's approach to measurements of technological change consists of two distinct but related approaches. In the first case an isodensity contour or a probability mountain represents the state of art (SOA) at any given point in time. The level of technological capability is given by the height of the mountain. Naturally the magnitude of the technological change can than be esteemed by the difference in the heights of successive mountain. In the second approach the SOA surface reduces to a point as a consequence of the transmutation of the original parameter space into a dimensional vector space. The successive points constitute a general pattern of the technological evolution that evinces a series of S-shaped curves.

3.6. The contribution of Archibugi (1988)

A main contribution to measurement and classification of the innovation came from the Science Policy Research Unit (SPRU) of the University of Sussex. Archibugi and Simonetti (1998) introduced a fundamental distinction between objects and subjects of innovation and on the basis of this assumption compared the two approaches alternatively emphasising the evolutionary and revolutionary characteristics of the technological change. The innovations were classified on the basis of three different criteria (Archibugi, 1988): 1) the technological group to which the innovation belonged (chemical, electronic, pharmaceutical, etc.); 2) the industry in which the institution that produced the innovation belonged; 3) the industry in which the innovation was to be used.

A diagram similar to a cube in which it is possible to place all the innovations identified represents this classification. The cube may in turn be broken down into three squared matrixes and this give a conceptual diagram that simplifies the theoretical interpretation of the industrial interdependencies identified for the analysis of the innovative processes.

3.7. Measurement of technical progress Ayres (1998)

Towards the end of the nineteen-nineties Ayres (1998) suggested a direct measurement of technological progress that could be quantified with reasonable consistency on the basis of historical data. The measurement suggested was the efficiency with which the (energy) resources are converted into final services. The author states that it would be better to construct an economic production function that estimates the technological change rather than dealing with technical progress as an unexplained residue (Solow, 1956, 1957).

4. Seismic approach to the measurement of technological change (2003)

The starting point for the present approach is the concept of good represented, for example, by the hours of work, free time, lifespan, level of pollution, travel time and so on. The concept of good is fully explained in Marshall (1890) who said:

[in the absence of any term in common use to represent all desiderable things, or things that satisfy human wants, we adopt the term GOODS for that purpose. All wealth consists of things that satisfy wants, directly or indirectly. All wealth therefore consists of goods; but not all kinds of goods are reckoned as wealth. The affection of friends, for instance, is a good; it is very important element of well being, but it is not ever reckoned as wealth, except by a poetic licence. Goods are material, or personal and immaterial].

The technological innovation (T) acts on good X, in come cases reducing it, in others increasing it, in any case the effect is always that of an increase in individual and social utility.

DEFINITION 2
Let X = good, and T = technological innovation, T_X = the technological innovation that acts on good X such that increase the level of user’s utility and social welfare.

Technological innovation in similar way to the earthquakes, is often the result of casual events, although it comes within the physiological nature of the evolution of the systems, and is difficult to forecast. A priori it is not possible to know exactly which spatial-temporal effects will cause the waves in the various areas in which they have spread. The method proposed here attempts to measure the impact of innovation both when the technological innovation has spread and is at an advanced phase of its evolution (ex-post), and when the evolution of the technological change is in its initial phases (5-10 years, ex-ante). In both cases the method is a tool of management and research policy for the correct planning of micro and macro economic development. The measurement after the event, to maintain the analogy with seismology which measures the intensity of earthquakes (one of the most unpredictable events) after they have occurred, can be useful since a country can learn from past innovations and equip itself with modern infrastructures, means of communication, human resources which are their strength in absorbing and accepting the impact of future technological innovations. This explains why a country with a large number of personal computers, modern telecommunication networks and trained human resources is advantaged in the absorption of new technological innovations, with respect to countries with less infrastructures and resources. One example is the greater spread, on average, of the Internet in Europe, with respect to Latin America or Asia.

DEFINITION 3

The forces that influence the intensity of the innovation and generate the causes of the economic impact of technological innovation within the economic system can be reduced to two variables:

a (adopters) = number of innovation adopters (people, firms, institutions, etc.)

w (welfare and utility) = utility of users and social welfare

REMARK 2. In the present approach, the first variable (*adopters*) is fixed and unique for all technological innovations, while the second which measures the *welfare* and *utility* will be different according to the type of innovation.

Table 4- Examples of variables of the model

Technological Innovations	*Fist variable*	*Second variable*
Farm tractors	Adopters	- Productivity per acre
		- Labour saving per acre, ect.
Catalytic muffler	Ibidem	- To decrease of the pollution
		- To decrease of pulmonary disease and cancer, etc.
Medicine	Ibidem	- Lifespan
Internet	Ibidem	- Time reduction of the communication or for searching information
		- To increase employment in ICT industries, etc.

DEFINITION 4

The function of the economic impact of the innovation or innovative impact is defined by the following equation:

Welfare of the innovation = f(adopters);
w = f(a), such that
$w: \Re \rightarrow \Re$ positive and continuous.

DEFINITION 5

Let $w = f(a)$ the function of economic impact of the technological innovation, such that $w: \Re \rightarrow \Re$ positive and continuous in [0, ξ], the MAgnitude of TEchnological CHange (MATECH) is defined as:

$$MATECH := Log_{10} \int_0^{\xi} f(a)da \qquad MATECH \in \Re^+$$

which supplies the area of dimensions ξ and *f(a)*.

- *The MATECH in the case of a function with two (real) variables*

If we consider two independent variables, for example adopters (*a*) and time (*t*) the function of the economic impact of the innovation is w = *f(a, t)* such that $w: A \subseteq \Re^2 \rightarrow \Re$ positive and continuous in A, limited and closed set; with reference to a system of Cartesian axis *Oxyz* the function geometrically represents a surface S which will all be above the plane *xy*. If A is the set of the plane thus defined:

$$A = \{(x, y): 0 \le x \le \xi,\ 0 \le y \le \upsilon\ \}$$

where ξ is the number of adopter, ν is the time of technological evolution, MATECH is defined as:

$$MATECH = Log_{10} \int_0^{\xi} \int_0^{\upsilon} f(a,t)dadt \qquad MATECH \in \Re^+$$

which supplies the volume of dimensions ξ, ν and *f(a,t)*.

- *Generalisation in a space with n-dimensions*

If we consider a multidimensional function (since there are many variables that can affect the economic impact of the innovation, x_1, x_2, …, x_n), the function of economic impact of the innovation will be of type $w: A \subseteq \Re^n \rightarrow \Re$ positive and continuous in A, limited and closed set. In a space with *n* dimensions, the function describe a hyperplane and the MATECH is thus defined:

$$MATECH := Log_{10} \int \ldots \int_A f(x_1, x_2, \ldots, x_n) dx_1 dx_2, \ldots, dx_n$$

$$MATECH \in \Re^+$$

which provide the volume under the hyper plane.

REMARK 3. The above approach calculates the innovative intensity on the basis of the area underlying the function of the innovative impact.

The second query we posed, was the graduation of the various innovations in order to show the power propagated in the economic environment, which leads to the following proposition.

PROPOSITION 2

Let T_1 innovation 1 and $w = f(a_1)$ the function of the innovative impact relative to T_{1X} positive and continuous in [a,b], let $w = f(a_2)$ the function of the innovative impact of the innovation relative to T_{2X}, let $\theta^{i}(T_j)$ the degree *i* of technological innovation *j*. If

$$Log_{10}\int_a^b f(a_1)da_1 < Log_{10}\int_a^b f(a_2)da_2$$

then the degree $\theta^{i+1}(T_{1X}) < \theta^{i}(T_{2X})$.

PROOF. If we consider a space of one (real) variable. Let *a*, the independent variable that the adoption of the innovations T_{1X} or T_{2X} tends to increase (for example productivity per acre, lifespan, etc.). Let us consider the values of *w* pre and post adoption of the innovation, to the respective degrees (before and after the application of the innovation of 7°, before and after the application of the innovation of 3°, after the 4° degree innovation is already in use, and so on). If β_1 is the slope of the function of innovative impact deriving by the application of an innovation T_{1X} of degrees θ^{i}, if the innovation T_{2X} is of degrees θ^{i-1}, than the slope β_2 of the function of innovative (i.e. $w = f(a_2)$) will be less than β_1.Therefore the area underlying $f(a_1)$, will be less than that underlying $f(a_2)$, and therefore the latter has a definite integral less than the former $f(a_1)$.

PROPOSITION 3

Let $w = f(a_1)$, the function of the innovative impact relative to the adoption of the innovation T_{1X}, positive and continuous in [a,b], $w = f(a_2)$ the function of the innovative impact relative to the use of the innovation T_{2X}, $w = f(a_n)$, the function of the innovative impact relative to the use of the innovation T_{nX}; let $\theta^{i}(T_{jX})$ the *ith* degree of the technological innovation *j* on *X*; If

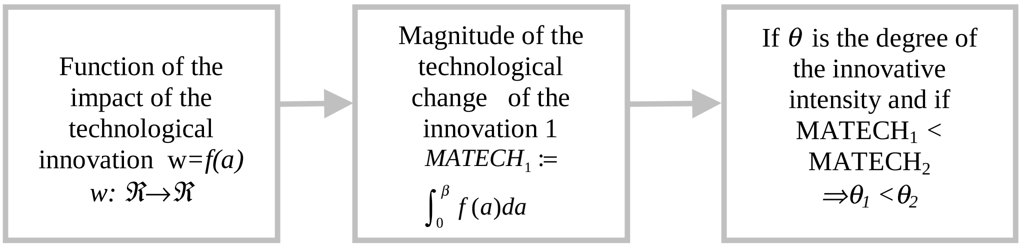
$$Log_{10}\int_a^b f(a_1)da_1 < Log_{10}\int_a^b f(a_2)da_2 < \ldots < Log_{10}\int_a^b f(a_i)da_i < \ldots < Log_{10}\int_a^b f(a_n)da_n$$

then the following relation $\theta^{1}(T_{1X}) < \theta^{2}(T_{2X}) < \ldots < \theta^{i}(T_{iX}) < \ldots < \theta^{n}(T_{nX})$ is true.

PROOF. The proof is similar to the previous proposition, applying the principal by induction.

REMARK 4. The logic underlying the grading of the intensity is similar to the structural approach of Knight (1985) which compares the structure of a new system with the preceding one. This methodology gives a precise measurement of the technological change in terms of increase in performance. The functions of the innovative impact are hypothesised positive (the dependent variable, *w*, increases as the independent variable increases) although the shape in space depends on the environment in which the innovative wave spreads. The function of the impact of the innovation will be represented by a continuous and positive function which can be estimated with a simple or multiple regression (linear or non linear). The integral calculus of the areas will make it possible to quantify the intensity and to grade it, making comparisons with other innovations.

The logical conceptualisation that links the quantity considered is the following:



- *Ex-ante measurement of the intensity of technological change*

The calculus of the ex-ante innovative intensity is an operation as difficult as weather forecasting because both in meteorology and technometrics there are numerous variables involved. In terms of management and research policy it would be interesting to draw indications of the initial diffusion of the innovation in order to see its potential growth and development (for example in the early years). The indicators elaborated for this purpose use both integral calculus as in the ex-post case and differential calculus. In the latter case we use a diffusive impact function whose dependent variable is the number of adopters and the independent variable is the time: a=f(t), adopters=f(time). The function will be estimated by the OLS (*Ordinary Last Square*) method, using polynomials of differing degrees, according to the circumstances, since the results are absolutely not affected. On this function we will calculate the following indicators in an interval of time [0, t], close to the origin of the innovation, in the case of indices which use integral calculus, while in instants of time t_0 and t_1, $\forall\ \varepsilon>0$ and infinitesimal small, $|\ t_0 - t_1|<\varepsilon$, in the case of indicators based on differential calculus.

Apart from the MATECH indicator, which can also be applied on the function of diffusive impact of the technological innovation, we have the following indices, using fundamental notions of kinematics:

1) velocity of the technological change $Log_{10}Vct = Log_{10}df(t)/dt = Log_{10}f'(t)$
2) acceleration of the technological change $Log_{10}Act = Log_{10}dVct/dt = Log_{10}f''(t)$
3) ratio between $Log_{10}f'/f''$

5. Application of the metric

The applications presented in this section concern both the measurements of ex-post-technological change and ex-ante; the latter will be used in order to give an empirical SIIN scale and some policy implications.

5.1. *Measurement of a fifth degree innovation: the mechanisation of the agriculture in Italy*

One of the most important economic activities in Italy is the production of grain (or corn) in both hard and soft species, the raw material for the production of pasta, of which Italians are the principal producers and consumers. In agriculture, and above all in the cultivation and harvesting of corn, various technological innovations have followed the industrial revolution.

In this section we intend to study how the adoption of certain technological innovations has influenced an indicator of utility in agriculture. For reasons of clarity the examples will be based on function of one (real) variable, but clearly the reasoning could be easily extended to two or multi-dimensional space.

We will consider the adoption of certain fundamental innovations such as the harvester, the combine harvester, spreaders and tractors with engines of less than 40 kW or more than 60 kW by Italian farmers as the independent variable. All these innovations are fundamental for improving the cultivation of this cereal.

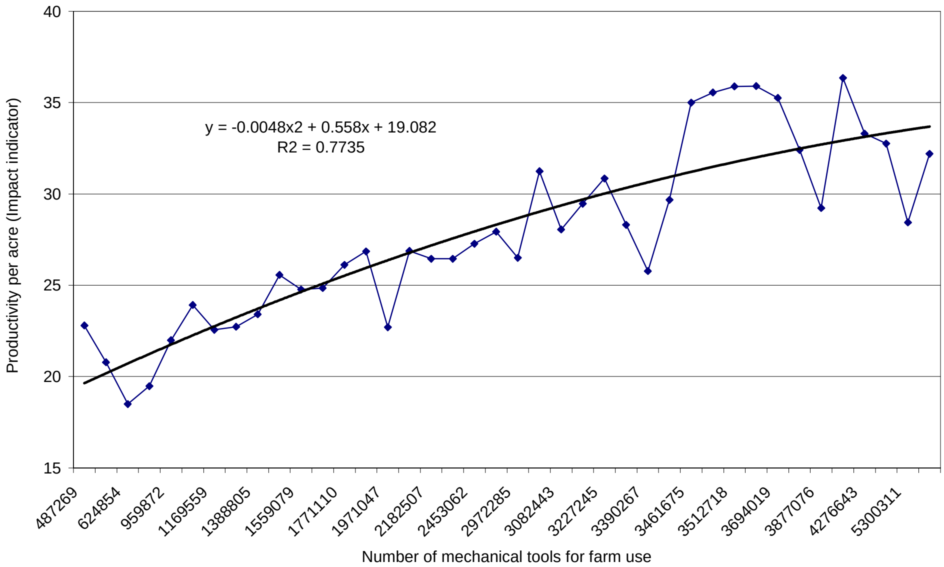
HYPOTESIS. It was considered opportune to approximate the welfare with a (dependent) variable represented by the productivity of quintal of grain per acre, which is an important indicator of utility created by the technological innovation.

The conceptual model is as follows:

Social Welfare or Utility =f(adopters of innovations)⇒ Productivity per acre =f(adoption of agricultural mechanical tools within the farms)

The data used was taken from the annual report of Italian ISTAT, Statistics and census of agriculture from 1963 to 2002. The scatter of the data was interpolated using the OLS method which (figure 1) gave the following function of the impact of the technological innovation:

Figure 1: Productivity per acre according to the use of mechanical tools in farm (period 1963-2002)



Source: Elaboration 2003 from ISTAT data

The intensity of the technological innovation is given by the following MATECH:

$$MATECH = Log_{10}\int_1^{40} -0.0048x^2 + 0.558x + 19.082dx = \left[-\frac{1}{3}\cdot 0.0048x^3 + \frac{1}{2}\cdot 0.558x^2 + 19.082x\right]_1^{40} = 4.325$$

REMARK 5. Here we have considered the impact of a fundamental innovation (the set as we have seen includes innovations of 1st, 2nd, 3rd, 4th, 5th degree) on productivity per acre, but if we consider innovations of a lower level, for example the impact on productivity of the use of pneumatic tyres on agricultural machinery (a 3rd degree innovation) comparing the structure of productivity prior to the innovation of pneumatic tyres and after the introduction of tyres, the MATECH will be lower since the increase in utility (productivity) is without doubt lower than the increase in productivity generated by the mechanisation of agriculture and given by the difference in yields before and after the introduction of farm tractors.

5.2. Ex-ante measurement of the innovation intensity of the tractor (5° degree) and Internet (7° degree)

The prior measurement of technological change, or the initial phase involves no little danger as shown in Sahal (1985). In this paper we will attempt to give some indications by considering two cases: the growth of Internet hosts throughout the world between 1981 and 2002, using the data of Network Wizards, indicators that are compared with those elaborated by the function of diffusive impact of the adoption of fundamental innovation of the tractor in the USA between 1920 and 1941 (Sahal, 1981).

The function of the diffusive impact of the technological innovation is *adopters = f(time)* and in the above two cases is respectively equal to the following relations:

1) *Adopters of Internet =f(time)*
2) *Adopters of tractors =f(time)*

Knowing that the innovation of the Internet hosts, according to our approach is an innovation with considerable social impact, since it has changed methods of human communication and is therefore of a higher degree than the tractor, which though of fundamental importance is considered of a lower degree. Therefore it is expected that the indicators of impact elaborated in the first innovation will be greater than the second.

We have considered the first ten years of evolution of the innovations to see whether it is possible to draw indications on the intensity of the innovative wave which will spread to the environment in coming years.

The first 10 years of the Internet host innovation (1981-1991) and the first decade of the tractor innovation (1920-1930) give rise to the following functions, estimated with the OLS method, R^2 and indicators:

- **Host internet**

$$y = f(t) = 34.675x^5 - 634.53x^4 + 4468.9x^3 - 14171x^2 + 19259x - 8462.3; \quad R^2 = 0.9972$$

$$f'(t) = 173.37x^4 + -2538.12x^3 + 13406.7x^2 - 28342x + 19259$$

$$f''(t) = 693.48x^3 - 7614.36x^2 + 26813.4x - 28342$$

MATECH is:

$$Innovative\ Magnitude = \left[5.78x^6 - 126.91x^5 + 1117.22x^4 - 4723.66x^3 + 9629.5x^2 - 8462.3x\right]_{1981}^{1991} = a$$

$$Log_{10}|a| = 19.0259$$

- **Tractors**

$$y = f(t) = -0.0008x^5 + 0.0747x^4 - 1.6819x^3 + 16.39x^2 - 3.9283x - 330.79 \quad R^2 = 0.9989$$

$$f'(t) = -0.004x^4 + 0.2988x^3 - 5.0457x^2 + 32.78x - 3.9283$$

$$f''(t) = -0.016x^3 + 0.8964x^2 - 10.0914x + 32.78$$

The magnitude is:

$$Magnitude\ of\ Innovation = \left[-0.00013x^6 + 0.01494x^5 - 0.420x^4 + 5.46x^3 - 1.9641x^2 + 330.79x\right]_{1920}^{1930} = a$$

$$Log_{10}|a| = 14.29$$

Table 5 - Impact indicators of the ten-year diffusion

Indicators	*Host Internet (1981-1991)*	*Farm tractor (1920-1930)*
$Log_{10}f'$ (velocity of the technological change)	15.42 $Log_{10}f'(x_{1986})$	10.72 $Log_{10}f'(x_{1925})$
$Log_{10}f''$ (acceleration of the technological change)	12.73 $Log_{10}f''(x_{1986})$	7.717 $Log_{10}f''(x_{1925})$
Magnitude (socio-economic impact)	19.02	14.29

Therefore considering the above indicators, in 1925 a manager or policy maker (five years after the introduction of tractors) and in 1986 (five years after the introduction of the Internet) could state that both innovations would have considerable diffusion and strong social-economic impact, greater in the case of the Internet than in that of the tractor.

Repeating the experiment in the case in which we only have access to the series of these two innovations in the first five years, the functions are the following:

- Host internet: $y=308.04x^2-1293.4x+1399$; $R^2 = 0.958$
- Tractor: $y=3.625x^2+31.454x+303.1$; $R^2 = 0.998$

Table 6 - Impact indicator five-year diffusion

Indicators	*Host Internet (1981-1986)*	*Farm tractor (1920-1925)*
$Log_{10}f'$ (velocity of the technological change)	616.08*x*-1293.4	7.25*x*+31.454
$Log_{10}f''$ (acceleration of the technological change)	616.08	7.25
Magnitude (socio-economic impact)	9.78	7.79

Even in the first five years we can see that the indicators show a greater force of propagation for the first innovation than for the second, and according to the seismic approach it is possible to conclude that the socio-economic impact of the Internet will produce greater effects on the environment than the innovation of tractors.

Table 7 - Empirical Scale of the innovative intensity (SIIN)

TECHNOLOGICAL CHANGE					
Innovation degree		*Level*	*Intensity*	*MATECH*	*Example*
1st group	I = 1°	Low	Lightest	[0; 6.5[	
	II = 2°		Mild		
	III = 3°		Moderate		
2nd group	IV = 4°	Medium	Intermediate	[6.5; 8.9[	
	V = 5°		Strong ◄		**Farm Tractors**
3rd group	VI = 6°	High	Very strong ◄	[8.9; +∞[	**Internet**
	VII = 7°		Revolutionary		

REMARKS 6. The above scale is valid only for the first five years following the introduction of the innovation, if the period of evaluation of the ex-ante impact is to be extended or reduced it is necessary to re-calculate the empirical values, in any case the SIIN gives an initial indication of the socio-economic impact of the technological change introduced by the innovation, in spite of the limits set out and the risks which will be explained in the next paragraph.

6. Conclusions

The aim of this paper is to construct a scale of innovative intensity that synthetically and systematically grades all the types of taxonomic typology of innovations existing in literature, and to construct a metric of innovation based of the economic impact on the socio-economic system. The idea of constructing a scale of innovative intensity is born because, as we have seen, the taxonomy proposed by Archibugi, Freeman, Pavitt, Durand, Abernathy, Clark and others, uses differing denominations to indicate the same type of technological change. This diversity is not considered a heterogeny (different elements that make up the innovation) but rather a heterophylly (differing forms of innovation with a common origin and genes). The latter generates different denominations of innovations, which are substantially similar, but differ in the form. For this reason it is necessary to build a common denominator of technological change, which is the innovative intensity, depending on the number of users and the effects on the environment (consumers and firms) and/or objects involved (means of communication, infrastructures, etc.). The increase in innovative intensity indicates a greater number of adopters with a series of increasing mutations in the geo-economic environment, also in terms of an increase in standard of living. The indicator that measures this force is the MATECH (MAgnitude of the TEchnological CHange).

The measurement of the intensity of the technological innovation as a growing function of the number of adopters (*a*) and the social welfare /utility (*w*), shows the effects caused by the spread of innovative waves in the environment. In other words, when passing from an innovation of I degree intensity to VII degree, there is an increase both in users (consumers, firms, institutions) and environmental changes (sectors, markets, industrial dynamics, competition and well being). The intensity of the VII degree is reserved for those innovations, and only those, that change human communication and have mass diffusion, while biotechnology and new materials are positioned in VI degree and not VII, unlike certain authors (Tidd et al., 2001).

A metric of the innovation, however correct, cannot ignore the temporal dimension and cannot be positioned too early in its evolution, since research has shown that certain technological innovations, though superior, may be subject to the lock-in effect to the advantage of lesser innovations which use their path-dependency (for instance the QWERTY keyboard documented by David, 1985).

The seismic approach starts from the consideration that innovative waves spread through the economic environment, causing a series of changes and the more these interest people and increase individual and social utility, the greater their intensity and therefore their level on the scale.

Within the theoretical structure of the seismic approach it is possible to find some logic from the approaches used in literature for the measurement of technological change. Above all the seismic approach uses both a macro point of view, and a micro as explained in paragraph 2. It is an approach that focuses on the objects (Archibugi, 1988; 1998), evaluating the economic-social impact of the innovation. The hedonism of the seismic approach differs from the sense of Court, Stone and Lancaster, and lies rather in the increase in human pleasure offered by the innovation, such as the increase both of individual well-being (for example the benefits of a medicine for the adopters) and the social benefits, with a significant impact on the wealth of nations. As in Dodson's approach, the technological change develops with the surfaces that are planes in a bi-dimensional space or hyper-planes *n* dimensions, but unlike this evaluates the economic impact of the technological innovation calculating the volume underlying these surfaces. Majer's functional approach (1985), like other approaches, considered certain attributes of the technology which are indicators of performance. Here we consider exogenous performance indicators, not the endogenous attributes: which human activities the technological innovations improve?

For example in the case of the tractor, the productivity per acre was increased, the number of working hours was reduced, the quality of the produce was improved, and so on. Knight's structural approach (1985) can be used when two performance structures are compared (e.g. productivity per acre) pre- and post- innovation. The differences between these two structures will also determine the degree on the SIIN scale. We have seen that an innovation with a high degree has a greater performance structure (increase in productivity) than one of a low degree. The seismic approach, considering the analogy with geophysics, considers that the innovation spreads through the environment with waves that they are those identified by Sahal in his holistic approach; Sahal also represented the SOA with mountains of probability which emerged on a plane and the magnitude was given by the height. The area underlying (weight) gives the magnitude of the seismic approach.

The application used to describe the magnitude of innovative intensity is clearly a simplification, since in reality it is more correct to write a function of innovation and diffusion impact as $f\colon \mathfrak{R}^n \rightarrow \mathfrak{R}^n$. Therefore it would be more correct to write the dimension of innovative intensity using the following form of the magnitude:

$$MATECH := \int \ldots \int_A f(x_1, x_2, \ldots, x_n)\, dx_1 dx_2, \ldots, dx_n$$

As far as the functional form *f* with which the path dependency of the technological innovation (David, 1993) develops depends on a series of factors that Rycroft and Kash (2002) summarised as culture, institutions and organisational learning.

The scale of innovative intensity is a starting point for the measurement and classification of the economic impact of the technological innovation on the environment. The analogy with the Mercalli seismic scale is justified by the simplicity, since like the seismic waves as the intensity of the innovations increases so the effects and the geo-economic changes. In the future specific studies will aim to further empirically verify the approach, extending the application to functions of impact with *n* (real) variables in order to improve the SIIN, increasing the precision of the description of the effects and the possibility of generalisation of the tool for measuring technological change and technological forecasting. The path will be arduous and long, since the analysis and measurement of the complex variables of technological change cannot be traced to a single topic, but these difficulties represent a challenge to be taken up.

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