

Classifications of Innovations Survey and Future Directions

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ABSTRACT. The purpose of this paper is to focus on similarity and/or heterogeneity of taxonomies of innovation present in the economic fields to show as the economic literature uses different names to indicate the same type of technical change and innovation, and the same name for different types of innovation. This ambiguity of classification makes it impossible to compare the various studies; moreover the numerous typologies existing in the economics of innovation, technometrics, economics of technical change, management of technology, etc., have hindered the development of knowledge in these fields. The research presents also new directions on the classification of innovation that try to overcome these problems.

KEYWORDS: Classifications, Taxonomy, Technical change, Product, Innovation Patterns, Management of Technology, Economics of innovation

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INTRODUCTION

The capacity to innovate is an important strategic option for many firms and countries. It is also a central and enduring research theme for academics, which have spent the last 70 years defining, explaining and measuring innovation in its many forms. A popular and fundamental approach that has accompanied these studies is the classification of innovation, which is both a process (to classify) and an output of the process (a classification). The classification provides models for ordering, labeling, and articulating knowledge about the diversity of innovations. Classification helps us to arrange and structure our knowledge in a way that is more fruitful and transferable than a simple list of descriptions.

The classifications of technical change and innovation, and its interpretation, remains one of the most difficult problems for scholars to analyze, due to the several variables involved and because the innovation can have different causes of origin.

As classification is a common process in the physical, life and social sciences: the result is a diverse range of interpretations and frequent misuse of classification terms, theories and methods. Although the words "category" and "taxonomy" are almost synonyms, they are very different in age. As early as 2,300 years ago, the father of all taxonomies, Aristotle, often used the word "Kathegoría". The word taxonomy is, on the contrary, a recent one, dating to the first half of the eighteenth century. Several scholars, including Linnaeus, to classify minerals and animal and botanical species used it. The scientists and philosophers of the Enlightenment introduced this neologism by recovering an ancient Greek word (*táxon*, arrangement, array) and associating it to *nómos*. Since then the word has been very successful and is still used in natural sciences to classify species, minerals and the phenomena. It should be noted that the term flourished in the natural sciences a century before Charles Darwin proposed his theory of evolution, though in more recent times taxonomies have tried to describe and explain the static characteristics of objects as well as their evolving patterns. Over the last decades,

the word has also been imported in social sciences. Taxonomies are meant to classify phenomena with the aim of maximizing the differences among groups. The term taxonomy refers to a branch of systematics concerned with the theory and practice of producing classification schemes. Thus, constructing a classification is a taxonomic process with rules on how to form and represent groups (*taxa*), which are then named (*nomy*). The social sciences have two general approaches to classification: the empirical and theoretical. The principal difference between these two social science approaches is the stage at which a theory of differences is proposed and evidence then sought to validate the theory (Warriner, 1984; Rich 1992; Doty and Glick, 1994). Theoretical classifications in the social sciences begin by developing a theory of differences which then results in a classification of organizational types, known as a typology. Only when the classification has been proposed is a decision made as to where an entity belongs in the classification. With the empirical approach, social science classifications begin by gathering data about the entities under study. The data are then processed using statistical methods (numerical taxonomy) to produce groups according to the measures of similarity and statistical techniques used. Thus the overall aim is to use data to construct the classification, instead of supporting it, but in reality, data are seldom collected without an expectation about what they will reveal or validate. While, for example, a "taxonomy" is considered useful, if it is able to reduce the complexity of the population studied into easily recallable macro-classes, the "classifications" are often highly desegregated, both in natural and social sciences (Archibugi, 2001). Although the term classification has been used throughout this paper, there is no agreement about the general use of the term. Classification as an output (a product of the process of classifying) deals with how groups and classes of entities will be arranged, in accord with the taxonomic approach used (McKelvey, 1982). It is a framework (e.g. a matrix, a table, a dendrogram, etc.) for ordering and representing, regardless of whether a theoretical or empirical approach is used. The terms classification scheme or

classification system are often used to distinguish and identify classification as an output. Examples of such schemes and systems include the Linnaean System of nomenclature, the Periodic Classification of chemical elements, the Mercalli scale, the Dewey Decimal Classification System for organizing books and other bibliographic items and the North American Industrial Classification (NAIC) and Standard Industrial Classification (SIC) systems for naming and organizing industry sectors.

The purpose of this paper is to focus on similarity and/or heterogeneity of taxonomies of innovation present in the economic fields to show as the economic literature uses different names to indicate the same type of technical change and innovation, and the same name for different types of innovation. The taxonomies of innovation can be divided in two sets of analysis (section 1): economics of innovation and management of technology. Section two presents a discussion and the new directions in the classification of the technical change and innovation that try to overcome the previous problems.

1. CLASSIFICATION OF TECHNICAL CHANGE AND INNOVATION INTENSITY: A LITERATURE REVIEW

Souder and Shrivastava (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”.

Garcia and Calantone (2002) state that innovations are frequently classified in taxonomies in order to identify their innovation characteristics and the degree of innovativeness involved. According to Durand (1992) four different perspectives can be adopted in order to analyze the intensity and the significance of technical change: 1) Technological input: technical novelty or scientific merit; 2) Competence throughput: new requirements on the competencies (resources, skills and knowledge), transience (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.

Empirical studies classify innovations in two fields: 1) at the macro level, the characteristics of innovation that are new to the world, market or sector are considered (Maidique and Zirger, 1984; Lee and Na, 1994). In this case, the innovativeness is based on factors that are exogenous to the firm, such as the familiarity of an innovation to the world and the industry or the creation of new competitors due to the introduction of new innovations; 2) at the micro level, innovation is new to firm or to the consumer (More, 1982). Some researchers use both yardsticks (Ali *et al.*, 1995; Cooper, 1979; Cooper and de Brentani, 1991). The innovation classifications can be divided according to two fields of study. These two perspectives show different characteristics of innovation will be as described in the following sections.

1.1 Taxonomies of innovation in economics of innovation

After Schumpeter (1939), according to whom technical knowledge is acquired both through invention and innovation, economists identified several kinds of innovations within technical change (Mensch, 1979; Priest and Hill, 1980; Archibugi and Santarelli, 1989; Durand, 1992; Dosi, 1988; Clark, 1985; Freeman, 1984).

Pavitt (1984) classified innovation according to the firms that generate it, identifying four sectorial taxonomies. Pavitt intended the taxonomy to describe the behavior of innovating firms, to predict their actions and to suggest a framework for policy analysis. Taxonomy was composed of four main categories:

- The first was *supplier dominated* firms active in traditional industries such as clothing and furniture (i.e. firms which innovate by acquiring machinery and equipment).
- The second was *specialized suppliers* of capital goods and equipment who live in symbiosis with their customers.
- The third was *science-based firms* born to exploit new scientific discoveries in fields such as electronics, chemicals, pharmaceuticals and aerospace, where the main source of knowledge is associated with in-house R&D laboratories.
- The fourth was *scale-intensive* firms active in mass production industries.

In subsequent versions Pavitt has added another category to classify the emerging information-intensive firms, which have their main source of technological accumulation in the advanced processing of data and are typical in sectors or industries such as banking, retailing, internet, software, and so on. According to Archibugi (2001) this has led to the disappearance of one of the former categories: namely specialized supplier firms. According to Pavitt's latest thoughts, these firms are somehow forced to become information-intensive or scale-intensive or to become non-innovative: "We have also excluded a 'supplier dominated' trajectory since ... it leaves accumulated technological skills and strategic initiative with suppliers. Firms intending to move from this position try to adopt either scale-intensive strategies (e.g. certain textile firms), or information-intensive strategies (e.g. certain retailing firms)" (Pavitt *et al.*, 1989, p. 96-97). Archibugi *et al.* (1991), state that supplier-dominated firms have a distinctive and significant technological trajectory and can be equally innovative by acquiring machinery and capital equipment.

Freeman *et al.* (1982), Freeman and Soete (1987) categorize various types of technical change and distinguish among:

– INCREMENTAL INNOVATIONS. *These occur more or less continuously in any industry or service activity, although at a varying rate in different industries and over different time periods. They may often occur, not so much as the result of formal research and development activity, but as the outcome of inventions and improvements suggested by engineers and others directly engaged in the production process, or as a result of initiatives and proposals by users. Many empirical studies have confirmed their great importance in improving the efficiency in use of all factors of production, for example Townsend's (1981) study of the Anderton shearer loader in the British coalmining industry. They are particularly important in the follow-through period after a radical breakthrough innovation and frequently associated with the scaling up of plant and equipment and quality improvements to products and services for a*

*variety of specific applications. Although their combined effect is extremely important in the growth of productivity, no single incremental innovation has dramatic effects, and they may sometimes pass unnoticed and unrecorded. However, their effects are apparent in the steady growth of productivity, which is reflected in input-output tables over time by major changes in the coefficients for the existing array of products and services (Freeman *et al.*, 1982).*

– RADICAL INNOVATIONS. *These are discontinuous events and in recent times is usually the result of a deliberate research and development activity in enterprises and/or in university and government laboratories. They are unevenly distributed over sectors and over time. Freeman and Soete's research did not support the view of Mensch (1979) that their appearance is concentrated particularly in periods of deep recessions. They would agree with Mensch that, whenever they may occur, they are important as the potential springboard for the growth of new markets, or in the case of radical process innovations, such as the oxygen steelmaking process, of big improvements in the cost and quality of existing products. Over a period of decades a radical innovation, such as nylon or the contraceptive pill, may have fairly dramatic effects, but in terms of their economic impact they are relatively small and localized, unless a whole cluster of radical innovations are linked together in the rise of entire new industries and services, such as the synthetic materials industry or the semiconductor industry. Strictly speaking, at a sufficiently disaggregative level, radical innovations would constantly require the addition of new rows and columns in an input-output table. But in practical terms, such changes are introduced only in the case of the most important innovations and with long time-lags, when their economic impact is already substantial (Freeman *et al.*, 1982).*

– NEW TECHNOLOGICAL SYSTEMS. *Keirstead (1948), in his exposition of a Schumpeterian theory of economic development, introduced the concept of 'constellations' of innovations, which were technically and economically inter-related. Obvious examples are the*

clusters of synthetic materials innovations and petrochemical innovations in the thirties, forties and fifties. They include numerous radical and incremental innovations in both products and processes (Freeman et al., 1982).

- CHANGES OF TECHNO-ECONOMIC PARADIGM (TECHNOLOGICAL REVOLUTIONS). *These are far-reaching and pervasive changes in technology, affecting many (or even all) branches of the economy, as well as giving rise to entirely new sectors. Examples given by Schumpeter were the steam engine and electric power. Characteristic of this type of technical change is that it affects the input cost structure and the conditions of production and distribution for almost every branch of the economy (Freeman et al., 1982).*

A change in techno-economic paradigm thus comprises clusters of radical and incremental innovations and embraces several 'new technology systems' (Coccia, 2005). Once a new Techno-economic paradigm has become established throughout the economy it may be described as a 'technological regime'. Nelson and Winter (1982) have also used the concepts of technological regimes and of natural trajectories in technology. Their 'General natural trajectories' correspond perhaps most closely to 'paradigms'. Bresnahan and Trajtenberg (1995) state that technical progress and growth appear to be driven by a few "General Purpose Technologies" (GPT's) such as steam engine, electric motor and semiconductors. GPT's represent the technological regimes or change of techno-economic paradigm and are characterized by pervasiveness, inherent potential for technical improvements, and innovational complementarities, giving rise to increasing returns-to-scale.

Dosi (1982) used the expression 'change of technological paradigm' and made comparisons with the analogous approach of Kuhn (1962) to 'scientific revolutions' and paradigm changes in basic science. In these terms 'incremental innovation' along established technological trajectories may be compared with Kuhn's normal science. Whilst strict analogies are out of

place the concept of paradigm change has the bringing out the elements of inertia in the system. Whilst there are similarities in all these concepts, the approach of Perez (1985) is the most systematic and has some important distinguishing features in relation to the structural crises of adaptation with which we are concerned. She argues that the development of a new "Techno-economic paradigm" involves a new "best practice" set of rules and customs for designers, engineers, entrepreneurs and managers, which differs respects from the previously prevailing paradigm. Changes of Techno-economic paradigm are based on combinations of radical product, process and organizational innovations. They occur relatively seldom (perhaps twice in a century) but when they occur, they necessitate changes in the institutional and social framework, as well as in most enterprises if their potential is to be fully exploited. They give rise to major changes in the organizational structure of firms, the skill mix and the management style of industry. The Schumpeterian "creative destruction" may thus be only partial in some instances. Note that nothing is said so far about what is being changed, nor in what sense the change is taking place. Nelson and Winter (1982) introduced the concept of technological trajectories to describe both continuous changes and discontinuities in technological innovations: continuous changes are often related to progress along a technological trajectory - the direction of advance within a technological paradigm - while discontinuities are associated with the emergence of a new technological paradigm.

Forces from which technological innovation may originate are two: market pull versus technology push (Darroch and Jardine, 2002). In fact, for this reason innovations are often characterized as incremental versus radical. Dosi (1988) states that an incremental innovation is more likely to be a market pull innovation, while a radical innovation is generally originated by scientists and often incorporates new technologies or new combinations of existing technologies (Van de Ven and Garud, 1993). Thus, radical innovation is often a technology push innovation (Cooper, 1979; Green et al., 1995; O'Connor, 1998).

1.2 *Classifications of innovations within the management of technology (MOT)*

Within the MOT, the classifications of innovation are focused on product, competition, system of production and market. Abernathy and Clark (1985) provide the most important taxonomy. They define transilience as: the significance of innovation for competition depends on its capacity to influence the firm's existing resources, skills and knowledge - What we shall call its 'transilience'. Similarly in Dosi's words (1982; 1988): "Progress upon a technological trajectory is likely to retain some cumulative features". The market transilience scale is in the vertical dimension, and the technology transilience scale in the horizontal. This creates a transilience map, with four quadrants representing a different kind of innovation (Figure 1).

ARCHITECTURAL INNOVATION. New technology that departs from established systems of production, and in turn opens up new linkages to markets and users, is characteristic of the creation of new industries as well as the reformation of old ones. Innovation of this sort defines the basic configuration of product and process, and establishes the technical and marketing agendas that will guide subsequent development. In effect, it lays down the architecture of the industry, the broad framework within which competition will occur and develop. They have thus labeled innovation of this sort "Architectural"; it is graphed in the upper right hand quadrant of the transilience map.

INNOVATION IN THE MARKET NICHE. Using new concepts in technology to forge new market linkages is the essence of architectural innovation. Opening new market opportunities through the use of existing technology is central to the kind of innovation they have labeled "Niche Creation", but here the effect on production and technical systems is to conserve and strengthen established designs. There are numerous examples of niche creation innovation, ranging from the Timex example referred to earlier, to producers of fashion

apparel, and consumer electronics products. The portable radio or cassette player in Sony's Walkman, used established technologies to create a new niche in personal audio products. Innovation of this sort represents what Utterback (1996) has called sales maximization, in which an otherwise stable and well specified technology is refined, improved or changed in a way that supports a new marketing thrust. In some instances, niche creation involves a truly trivial change in technology, in which the impact on productive systems and technical knowledge is incremental. But this type of innovation may also appear in concert with significant new product introductions, vigorous competition on the basis of features, technical refinements, and even technological shifts. The important point is that these changes build on established technical competence, and improve its applicability in emerging market segments.

REGULAR INNOVATION. *The creation of niches and the laying down of a new architecture involve innovation- that is visible and after the fact apparently logical. In contrast, what they call "Regular" innovation is often almost invisible, yet can have a dramatic cumulative effect on product cost and performance. Regular innovation involves change that builds on established technical and production competence and that is applied to existing markets and customers. The effect of these changes is to entrench existing skills and resources. Research on rocket engines, computers and synthetic-fibers has shown that regular innovation can have dramatic effect on production costs, reliability and performance. Regular innovation can have a significant effect on product characteristics and thus can serve to strengthen and entrench not only competence in production, but linkages to customers and markets. It is important to note that these effects tend to take place over a significant period of time. They require an organizational environment and managerial skills that support the dogged pursuit of improvement, no matter how minor. The effects of a given regular innovation on competition are thus of less connect than the cumulative effects of a whole series of changes (Abernathy and Clark, 1985).*

	Disrupt Existing/Create New Linkages		
Conserve/Entrecth Existing Competence	Niche Creation	Architectural	Disrupt/Obsolete Existing Competence
	Regular	Revolutionary	
	Conserve/Entrecth Existing Linkages		

Source: Abernathy and Clark (1985)

Fig. 1: Transilience map

- REVOLUTION INNOVATION. *Innovation that disrupts and renders established technical and production competence obsolete, yet is applied to existing markets and customers, is the fourth category in the transilience map and is labeled "Revolutionary". The reciprocating engine in aircraft, vacuum tubes, and mechanical calculators are recent examples of established technologies that have been over thrown through a revolutionary design. Yet the classic case of revolutionary innovation is the competitive duel between Ford and General Motors in the late 1920s and early 1930s (Abernathy and Clark, 1985).*

A second classical and useful categorization distinguishes between product and process innovation. Utterback (1996) provides the definition of a discontinuous or radical innovation "change that sweeps away much of a firm's existing investment in technical skills and knowledge, designs, production technique, plant and equipment". Rothwell and Gardiner (1998) focus on technological discontinuity: innovations are radically new inventions establishing landmark new products, and as such, create new industries; reinnovations or improvements on existing product design (incremental), existing product (generational), new products (new mark products), improved materials, improving existing products (improvements), improving subsystems of existing products (minor details). Kleinschmidt and Cooper (1991) distinguish between high-moderate-low innovativeness. Anderson and Tushman (1986) actually suggested a typology of technical change that mixes the radical/incremental categories with the product/process classification. In a more dynamic way

Abernathy and Utterback (A-U, 1985) put forward a well-known model also linking these variables and describing patterns of innovations. The A-U model led to the concept that a "dominant technology" emerges, as innovation becomes essentially incremental. The A-U model, although purely descriptive, stands as a landmark in the strategic management literature on technological innovation. Moreover the S-curve has been used to describe the origin and evolution of technologically discontinuous/radical innovations (Figure 2).

A major problem that arises from A-U's model lies in their binary categorization of the intensity of innovation: are there not indeed innovations that are neither radical nor incremental? Abernathy and Clark (1985) acknowledged this point. They clearly suggest a continuum for technical change defined by polar extremes: their scale ranges from incremental to radical innovation. They do not say however what falls in between and where. There is indeed a continuously varying intensity of change. All radical innovation is not equally radical; all incremental innovation is not just an additional small improvement of what already exists. There are some intermediary changes that both disrupt and continue. The order breaking / order creating distinction suggested by Anderson and Tushman should allow for order breaking-creating categories.

Durand (1992), among these categories, introduces the micro radical innovations. In fact he states that "Moving from 64k DRAM's electronic memories to 128k then to 256k, etc., were by no means radical changes, nor were they simply incremental evolutions".

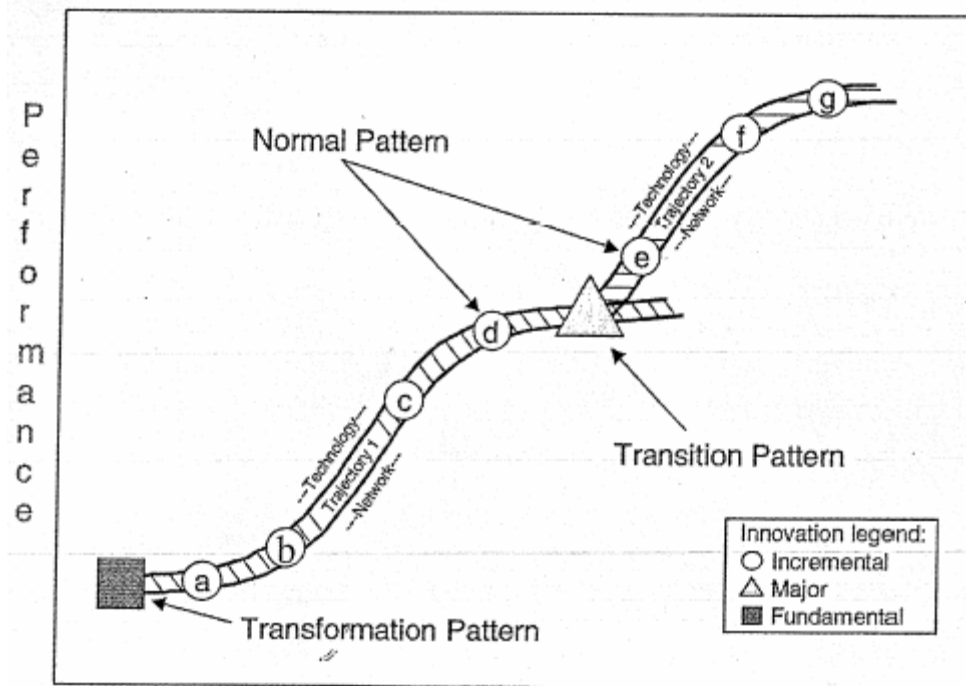


Fig. 2: Types of innovation. Source: Rycroft R. W., Kash D. E. (2002)

In synthesis the management of technology uses the following taxonomies in order to classify product innovation (Garcia and Calantone, 2002):

- eight categories – reformulated, new parts, remarkchandising, new improvements, new products, new users, new market, 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; Tidd *et al.* 2001);
- triadic categorization - low, moderate, high innovativeness (Kleinschmidt and Cooper, 1991); incremental, new generation, radically new (Wheelwright and Clark, 1992);
- dichotomous categorization – discontinuous, continuous (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 Gardiner, 1988); radical, routine (Meyers and Tucker, 1989); evolutionary, revolutionary (Utterback, 1996); sustaining, disruptive (Christensen, 1997); really new, incremental (Schmidt and Calantone, 1998; Song and Montoya-Weisse, 1998); breakthrough, incremental (Rice *et al.*, 1998); radical, incremental (Balachandra and Friar, 1997; Freeman, 1994).

Garcia and Calantone (2002) use the level macro versus micro, marketing versus technology perspectives and apply Boolean logic to identify three labels for innovations: radical, really new and incremental. The radical innovations are those which cause discontinuity of marketing and technology, both at a macro and a micro level (Van de Ven and Garud, 1993). Incremental innovations occur only at the

micro level and cause either discontinuity of marketing, or discontinuity of technology, but not both. Really new innovations include combinations of these two extremes. These three definitions show a reduction in the degree of innovativeness in the following way: radical → really new → incremental. Moreover, at the macro level, the discontinuities are exogenous to the firm. At both a macro and a 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.

2. DISCUSSION AND FUTURE DIRECTIONS

The abundance of types mentioned means that different types of innovation are called by the same name and the same innovation is classified in different manners. Gertrude Stein and William Shakespeare stated “a rose is a rose is a rose. And a rose by any other name would smell just as sweet”. 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 typologies existing in the economics of innovation, technometrics, economics of technical change, MOT, etc., have hindered the development of knowledge in these fields.

A new taxonomy that tries to overcome the limits of exiting classification it is the scale of technological innovation intensity, elaborated by Coccia (2005). The idea was to develop a way to measures the economic impact of innovation and to provide assessment of the effects on the geo-economic system. In fact, in the economics of innovation, there are no classifications for the effects of innovation on the economic system,

although in other fields there are many different scales used to classify (and quantify) 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 magnitude of earthquakes; the international scale of nuclear events (INES); the scale invented by the English admiral Beaufort to measure the force of the wind, the Douglas scale concerning the state of the sea, the Saffir-Simpson scale for Hurricanes, and so on. For this reason, a scale of technological innovation intensity, is a meta-taxonomy of the economic impact of technological innovation, subsuming less comprehensive taxonomies (Coccia, 2005). This new approach is called ‘seismic’ because the aim is to classify and quantify innovation and technical change through an evaluation scale similar to that used in seismology by Mercalli, who evaluate the intensity of earthquakes through the description of the effects on the geographical environment. In fact, according to this new approach to classify technical change, the socio-economic system is changed by innovations that modify the economic space with a series of effects both on the subjects and the objects (the technological intensity measures the strength of the technical change produced by the innovation within the economy). Moreover, the metrics of this approach quantifies the economic and social impact of technical change, over time and space, through a indicator called Magnitude of Technical Change (Figure 3).

The scale of innovation intensity is described in table 1. It shows that some of the taxonomies for innovations presented in economic literature are synthesized in new levels, called innovation degrees. This scale synthesizes the abundance of innovation taxonomies presented in economic literature where different types of innovation are called by the same name and same innovations are classified in different levels. The innovation degree allows a comparison among various innovations, which is impossible with the previous classifications.

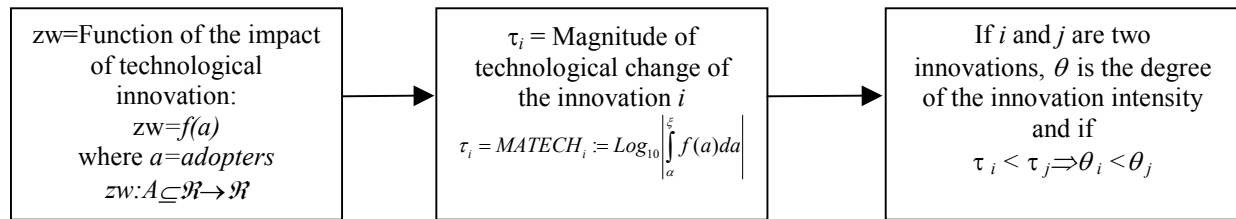


Fig. 3: Steps to measure the intensity of technological change according to the seismic approach

Tab. 1: Scale of innovation intensity

CLASSIFICATION OF TECHNICAL CHANGE			
Economic impact	Innovation Degree	Innovation Intensity	Some definitions of innovations used in economic literature
I SET Low Impact	I=1 st	Lightest	Elementary or micro-incremental (Coccia, 2005) Unrecorded (Freeman, 1994)
	II=2 nd	Mild	Continuous (Freeman <i>et al.</i> , 1982) Improvements (Mensch, 1979) Incremental (Freeman <i>et al.</i> , 1982; Priest and Hill, 1980) Market Pull (Dosi, 1988) Minor (Archibugi and Santarelli, 1989) Normal science (Khun, 1962) Regular (Abernathy and Clark, 1985)
	III=3 rd	Moderate	Major (Archibugi and Santarelli, 1989; Rycroft and Kash, 2002) Market breakthrough (Chandy and Tellis, 2000) Modular (Henderson and Clark, 1990) Non drastic (Arrow, 1962); Gilbert and Newbery, 1982) Really new (Garcia and Calantone, 2002)
II SET Medium Impact	IV=4 th	Intermediate	Evolutionary Technical (Moriarty and Kosnik, 1990) Micro-radical (Durand, 1992) Niche creation (Abernathy and Clark, 1985) Non drastic (Arrow, 1962; Gilbert and Newbery, 1982) Technological breakthrough (Chandy and Tellis, 2000)
	V=5 th	Strong	Architectural (Abernathy and Clark, 1985) Basic innovation (Mensch, 1979) Breakthrough (Tidd, 1995) Discontinuous (Archibugi and Santarelli, 1989) Discrete (Priest and Hill, 1980) Drastic (Arrow, 1962; Gilbert and Newbery, 1982) Fundamental (Mensch, 1979) Radical (Freeman <i>et al.</i> , 1982) Technology push (Dosi, 1988)
III SET High Impact	VI=6 th	Very strong	Clusters of innovations (Freeman <i>et al.</i> , 1982) Constellations of innovations (Keirstead, 1948) Innovation systems (Sahal, 1981) New technological Systems (Freeman <i>et al.</i> , 1982)
	VII=7 th	Revolutionary	Change of Techno-economic paradigms (Freeman <i>et al.</i> , 1982) Change of technological paradigms (Dosi, 1982) Cluster of New technological systems (Coccia, 2005) Revolutionary (Abernathy and Clark, 1985) Technological regimes (Nelson and Winter, 1982) Technological revolutions (Freeman <i>et al.</i> , 1982; Freeman, 1984)

Coccia (2005) argues that although the causes that originate innovations are different, the effects on the geo-economics systems are always similar. For instance the effects produced by the VII degree innovations are the following:

- The means of human communication are radically changed and a new means of communication, that heavily affects all the economic subjects and objects, has origin, forcing all those who use it to change their habits. A new Techno-economic paradigm is born. The innovation of VII degree produces the following effects on Consumer, Firm and Market.
- *Consumer.* Changes in lifestyle, in habits tendency to save and invest, etc. The standard of living and well being are considerably improved.
- *Firm.* Involves all the firms within the economic system. The organizational structures and production processes are changed. New firms offering new services and/or products are founded. Production, organizational and management methods change.
- *Market.* This innovation revolutionizes all the existing markets, creating new ones. The markets become increasingly turbulent.

3. CONCLUDING REMARKS

Nowadays, technical change and innovation play more and more a fundamental role in various fields. Technical change can display in several types of innovation which have different intensity. The classifications and measurements of technical change are important indicators for the economic growth, the consumers' behavior, the analysis of international trade and the evaluation of monetary and fiscal policies. The measurement of technology is the key to the forecasting and management of product and process innovations.

The economic literature on technical change uses different names to indicate the same type of technical change (Archibugi, Freeman, Pavitt,

Durand, Abernathy, Clark and others). This diversity is not considered a heterogeny (different elements that make up the innovation) but rather a heterophylly (differing forms of innovation with common origin and genes). The latter generates different definitions of innovations, which are substantially similar, but differ in the form. From this survey I conclude that there is a relatively large number of individual and unconnected innovation classifications that tend to be disconnected from each other or ignore the different input and process issues responsible innovation diversity. For this reason the new directions to classify the technical change are based on common denominators, such as the innovation intensity degree that is based on the effects of innovation on the geo-economic system (subjects, such as consumers and firms; objects such as: means of communication, infrastructures, etc). In general the measurement and classifications of technology is carried out after that the innovative event has occurred. This logic has limits for technological forecasting and foresight but to measure innovation – a posteriori - can be useful, in similar way is useful to measures and classifies the intensity of earthquakes (one of the most unpredictable events) after they have occurred. In fact, a country can learn from past innovations and equip itself with modern infrastructures, means of communication, trained human resources, which are its strength in absorbing and accepting the impact of future technological innovations. This explains why a country with a large number of computers, modern telecommunication networks, universities, modern means of communication, science parks and trained human resources is advantaged in the absorption of new technological innovations and has a competitive advantage in comparison to countries with less technological infrastructures and resources. Moreover all taxonomies present a level called revolution, which indicate a high impact of innovation. For instance, within the scale of technological intensity the intensity (Coccia, 2005) of the 7th degree innovation is strictly limited to those innovations that change human communication and have mass diffusion. Seventh degree is similar to the technological revolution of Freeman and Soete (1987) and

revolution – innovation of Abernathy and Clark (1985).

In all, the difficulty presents to classify and measure the innovations is due to several variables of the technical change function. This is a serious problem for all economists and scholars since the measurement and classifications of technical change and innovation cannot be traced to a single discipline, but these difficulties represent a challenge still to be tackled.

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