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Neo-Schumpeterian Long Wave Theory and Nanotechnology: Assessing the Future of Manufacturing Industry

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Abstract

While the initial ten years of the twenty first century have not ended yet; global capitalism is experiencing a widespread and in-depth economic crisis in 2007-2008. In this crisis environment, criticisms against mainstream economics increased and debates regarding the future of capitalism started. In order to envisage the future of capitalism, it is necessary to scrutinize the long-term structural tendencies of the capitalist development. With reference to the approach of the Russian economist Kondratieff that expounds capitalist development with the cycles that last 40 to 60 years and that follow each other, the long waves of capitalist development are named "Kondratieff Waves." Neo-Schumpeterian theory or the techno economic paradigm approach presents an approach that combines Kondratieff's long wave theory with Schumpeter's economic development theory and that explains capitalist development with technological change. According to this approach, capitalist development process consists of five Kondratieff waves that have been consecutive to date. The latest global financial crisis may manifest itself as the symptom of the termination process of the long wave by turning into a deepening economic depression. This research tries to review how nanotechnology contributes economic growth and change the structure of manufacturing industry at the eve of the sixth Kondratieff wave. This framework is investigated by using comparative case study of advanced and Newly Industrialized Countries.

Keywords: Long Waves, Nanotechnology, Technoeconomic Paradigm, Manufacturing Industry

1. Introduction

2007-2008 crises that went down history as the first global crisis of the twenty first century and which is qualified as the "great depression" as well brought together the debate about the economic growth and industry policy of the countries.

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Starting from 2008 American mortgage crises have transformed to global crises and hit many national economies. While world's growth slowed down, industrial production declined owing to both global and domestic demand collapse in many countries. This widespread economic crisis that is ongoing in the academic circles is related with how capitalism will get out from the ongoing stagnancy conjecture and how a stable and sustainable economical growth would be ensured in the world's economics by reducing the uncertainties after the crisis. While understanding of the fact that the stagnancy caused by the crisis, which commenced in the global financial markets and dominated the real economy by expanding in a short period, would last long caused to questioning of the current industry policies, it accelerated the new industry policy searches that constitute an alternative for such policies as well. Countries are in search of a new industry policy for the revitalization of the industry and for recapturing permanent growth. In today's world where the demands for reindustrialization increased, priority is set to render the country's industry policies with the growth targets and base them on a sustainable growth strategy (OECD, 2013). The moving force of this new industrialization process will be the new generic technologies. In the OECD countries, share of the manufacture industry within the national production-added value and employment has been diminishing for the last thirty years. While the industry is losing its competitiveness, service sectors are growing more rapidly than the industry sector.

While growing literature on recent crises focuses on financial market failure, bad governance and wrong policy, few scholars have taken account on structural roots of global crises (e.g. Šmihula, 2009; Gore, 2010; Devezas, 2010; Korotayev and Tsirel, 2010; Perez,2009). Indeed; financial boom-bust cycle stemming from financial market failure or lack of sufficient regulations on market is conclusion of *the permanent crises* rather than the cause. Actually, structural roots of the recent crises should be searched for long run development dynamics of capitalist economy .It is the main way to understand this long run development dynamics is long wave theory. This approach was arisen by the seminal contribution of the Soviet economist Nikolai Kondratieff. He observed long-term economic fluctuations in cycles of 40 to 60 years (Kondratieff, 1935). This approach was transformed to analytical and theoretical framework for understanding technological evolution and social change in historical time by Schumpeter and his pursuers.

This study aims to analyze impact of nanotechnology on future of manufacturing industry and tries to review how nanotechnology contributes transformation of manufacturing industry structure on the eve of the sixth Kondratieff wave. This framework is investigated by using comparative case study of developed and Newly Industrialized Countries.

This paper will be organized as follows: In the first section, long wave theory from neo-Schumpeterian perspective will be handled. In the second section, potential impact of nanotechnology on industry and its opportunity window will be drawn. In the third section, role of nanotechnology research on industrialization strategy will be discussed via comparative case study of developed and Newly Industrialized Countries.

2. Long Waves Theory of Capitalist Development and Schumpeter's Contribution

The theories that try to explain the capitalist development on the basis of long waves that are widening and narrowing down in the stagnancy and crisis environment in connection with the termination of the postwar expansion period after the 1970s are gradually attracting the attentions of more and more economists. Differently from the short term fluctuations referred to as the business cycles, development dynamics of the capitalist economy defined as long waves have become a rapidly growing field of research. According to the fundamental result reached by these different studies, economic development in capitalism forms as the consecutive big waves and the impacts and results of each of these waves expand within an entire period and leave its place in time to the subsequent wave of progress. The conjecture theories that assert that economy navigates with long termed fluctuations with ups and downs and that it has a wave consisting of improvement, well-being, shrinkage, and crisis stages has a 40 to 50 years of life have presented for the first time in the article entitled "Long Waves in Economic Life" published by N. D. Kondratieff in 1919 (O'Hara, 1994). These long termed fluctuations can be considered to have consisted of four main periods as improvement, well-being, shrinkage, and crisis. In 1939, Joseph Schumpeter suggested naming the cycles "Kondratieff waves (K-wave)" in his honor (Schumpeter, 1939).

Since the late 18th century, economists have empirically proven five Kondratieff waves. The fifth Kondratieff wave ended with the turn of this century, while a new long cycle, the sixth Kondratieff, has begun (Linstone and Devezas, 2012). The sixth wave will likely be focused on emerging research areas such biotechnology, "bioelectronics", nanotechnology and new materials sciences (Perez, 2008; Klein, 2005).

Table 1: The Kondratieff Waves

	Technological revolution	**Period of technological revolution**
1	Water-powered mechanization of industry	1780 – 1848
2	Steam powered mechanization of industry	1848 – 1895
3	Electrification of industry, transport and the home	1895 – 1940
4	Motorizations of transport, economy and war	1941 – 1973
5	Computerization of economy	1973 –

Source: Freeman, and Lauça 2001:141

Long wave theory was progressed by contribution of Joseph Schumpeter, one of the original social scientist of the twenty century (Fagerberg, 2003). He developed an original approach focusing on the role of innovation and entrepreneur in economic life (Schumpeter,1934). Economic development had to seen as a process of qualitative change which is determined by innovation in Schumpeter's opinion. Innovation, in his view, as a new combination of existing resource was realized by entrepreneur. Schumpeter his dynamic theory used analyzing long run development of economy as well. According to his theory, K-wave begins with technological innovations, which then become the cornerstones of a prolonged economic upturn (McCraw, 2006). Innovations have clustered in certain industry and trigger new bursts of productivity throughout the entire economy. Productivity of whole economy began to decline because booster impact of innovations ran out. This periodic upward-downward motion of economic activities, so-called long wave, in world economy mainly has been determined by clustering innovation.

Schumpeter has scrutinized the capitalist system within the framework of the non-balance evolutionary process instead of the neoclassic stable fixed state balance approach. Innovation underlies the foundation of Schumpeter's this change dynamic, which is internal with its capitalist development.

Innovation is defined as the presentation of the current resources as the new amalgamations. (Schumpeter, 1934: 66) There are five basic innovation forms that are the source of an economic change.

a. New consumables: development of the new products qualified as the product innovation.
b. New production methods: use of the new techniques in the production qualified as the process innovation.
c. New markets: development of the new markets or new marketing possibilities.
d. New raw material resources. : start of utilizing of new resources.
e. New industrial organizations: changes in the form of business conduct qualified as organizational innovation.

Those who realize innovations are the entrepreneurs. An entrepreneur is the person who pursues new products, who is in new searches in terms of the management of the firm, and who explores new markets. The role of an entrepreneur is to renew and remedy a production system by means of utilizing an in invention or a technique that has never been used in general. (Schumpeter, 1942:202) Schumpeter's entrepreneurs do not come from a certain class; they constitute a talented minority (Heilbroner, 1999). This elite human type exhibit talent differences within itself. Differentiation of the agents, which ensure technological development, within themselves, constitutes the engine of the technological diversity and evolutionist development. The motive that activates an entrepreneur is profit. Profit is the gain of conducting innovation and obtained by entrepreneurs. In the appearance of innovation, bank loan plays a central role. In addition to the creative entrepreneur, risk-undertaking banker is the most significant element of an economic development. (Hanusch and Pyka, 2007: 282) There is an inseparable union between the entrepreneur and the banker. According to Schumpeter, internal change dynamics of a capitalist economy is "innovation (reason)", "entrepreneur (subject)" and "bank loan (instrument)" (Gürkan, 2007:254). Schumpeter defines capitalist economy as an unending "creative destruction" process. Every firm within the capitalist system try to increase its market share and have a dominant state by means of finding a new design, cost reducing endeavor, a new product, and new inputs as well as of developing new production methods. However, each innovation destroys the monopolist power preceding itself. This creative destruction waves constitute the basic dynamic of the long term development of the capitalist economy.

Basic factor underlying the long fluctuations following a trend of decrease and increase in the capitalist development is that while new sectors where the profit shares and investment opportunities are extremely high depending on the innovation aggregations are appearing, the sectors based on the current matured technologies are disappearing in line with their loss of their profitability ratios. From this time, the topic of the causes of long waves remains central in the agenda of the neo-Schumpeterian tradition which is placed itself opposite to neoclassical economics, based on maximization behavior of rational economic agents. This analytical framework has been developed via contributions of neo-Schumpeterian scholars since beginning of the 1980s.

3. Neo-Schumpeterian Techno-economic Paradigm Approach

Neo-Schumpeterian approach expounds the long waves of capitalist development within the framework of the scientific advancement model developed by Thomas Samuel Kuhn, an American physicist, historian, and philosopher of science. According to Kuhn, a stability period that is referred to as a normal scientific period is interrupted by a crisis period and this crisis period allows the inauguration of a new normal scientific period by causing the appearance of the scientific revolution (Kuhn, 1962).Current scientific paradigm defines the rules, standards, and scientific research methods shared by scientists, and create an ambiance of reconciliation for the continuation of the research tradition. Neo-Schumpeterian theory, or technoeconomic paradigm approach, is a theory that combines Kondratieff's long waves theory with Schumpeter's economic development theory and that focuses within the capitalist development process on technological change (Taymaz, 1993: 14).

Techno-economic paradigm approach which focused on long run socioeconomic and institutional change dynamics of capitalistic economy by using K-wave framework was based on this neo-Schumpeterian tradition. Dosi (1982) defines technology paradigm as a "model and pattern of solution of selected technological problems based on selected principle from the natural science and on selected material technologies." This conceptual analysis provides framework to understand how technology change in specific direction and why this direction transforms. The paradigm thus limits the possible directions technological development may take. According to this approach, institutional environment is itself endogenous factor which is determined by technological development.

Moreover techno-economic paradigm approach provides theoretical background for analyses long wave in economy and understanding the groundbreaking transformation in society. Changes in techno-economic paradigms may be said to redefine the trajectory not only of the technological and economic spheres but also of the social sphere (Pérez, 2008).Each techno-economic paradigm requires a new infrastructure allowing the new technologies to be diffused throughout the economic system, while the dominant characteristics of the production system are restructured to incorporate processes that allow new products to be created and distributed. For each paradigm, there are common denominators that influence the behavior of the relative costs, supply and diffusion of new technologies and the organization of production processes (Dosi, 1984). Thus the notions of trajectory or paradigm highlight the importance of incremental innovations in the growth path following each radical innovation. Though it is true that major innovations have a central role in determining new investment and economic growth, expansion depends on incremental innovation (Perez, 1983; Perez, 1985; Perez, 2002).

According to Schumpeter, every long wave is unique because of the technological newness differences in that period on one hand and of the difference of the historical events such as wars, discovery of gold mines, or famine on the other. However, in the explanation of this long term fluctuations, the most important factor is innovations, which is the engine of capitalist growth source of the profits of the entrepreneurs (Freeman and Soete, 1997). The expression of technoeconomic paradigm contains, as a meaning, the economical selection process among a range of innovations that can be technically realized. In reality, a new paradigm's becoming clear takes relatively a long time (a few decades); expansion of this within the entire system takes longer. This expansion contains an interaction process where, among the technological, economic, and political forces, corporate innovations (or corporate renewals) gain utmost importance (Freeman 1990:3). For understanding the technoeconomic paradigm change, basic analysis level is the innovations also highlighted by Schumpeter. Some changes stemming from the innovations in their technological systems are so long-ranged in terms of the results they create that they have a substantial impact on functioning of entire economy.

These changes form the phenomenon that Schumpeter names as "creative gales of destruction" that constitutes the main axis of his "long cycles in the economic development." Basic power underlying such creative destruction gales is the innovations that intensify in a certain historical period. Innovations are analyzed under four headings (Freeman and Perez 1988:45-47):

1. Incremental Innovations: They are the minor technological changes that are encountered in the industry and services, that take place in different rations among industries from country to country, and that provide very little continuation. They are the innovations that mainly take place not as a result of the R&D studies but depending on the learning-by-practicing processes and the improvement of the engineering activities taking part in the production process or through the impressions and recommendations of the users.
2. Radical Innovations: They are the important and effective technological changes that appear as a result of the R&D activities, that do not exhibit a continuous feature, and that take place unequal among sectors. Even though the radical innovations such as nylon create significant structural changes, their impacts on the generality of the economy are relatively small and local.
3. Technological System Changes: Deep-rooted technological changes causing the formation of the new sectors that affect the different sectors in economy. It stems from the amalgamation of the radical and incremental innovations in the manner that it will cover the organizational innovations affecting one or multiple firms. Synthetic substance innovations, petro-chemistry innovations, and internal combustion motor innovations can be exemplified for such changes.
4. Techno-economic Paradigm Changes: (Technological Revolutions): Some technological system changes have substantial impacts on the entire behavior of economy. These types of changes take place by way of the aggregation of the radical and incremental innovations and joint appearance of numerous technological systems as a result of it. Characteristic feature of a technological revolution is not its widespread impact on every branches of economy, not only on some products, services or sectors.

Technological revolutions; or creative destruction gales, create significant changes on the social structure. In order for these changes to expand along the entire economy, fundamental transformations in the manner of organization of production must be realized. Such technological revolutions cause the occurrence of rapidly shifting production functions for both the old and the new products. The extent of savings to be obtained in the labor or capital cannot be initially estimated completely; but the general economic and technical benefit in the design of the products and production method by means of using new technology become visible well by increasing gradually and new practical rules are also developed gradually.

Such shifts in the paradigm make it possible to make a significant spurt in the potential productivity but such spurt takes place initially only in a few leading sectors. These gains cannot generally take place without organizational and social changes in other sectors (Freeman 1990:4). In order for the new economic paradigm to be superior over the old paradigm, it has to have the factor that can be defined as a group of key inputs that are unique to the new paradigm. These factors must have the following conditions (Freeman and Perez 1988:48):

a) Low and rapidly decreasing production costs;
b) Possibilities of supply that seem to be endless in the long term;
c) In the entire economy, potential of use in many products and processes

Table 2: Seven Stylised Facts of Five Long Waves

Constellations of technical and organisational innovations (1)	Examples of highly visible, technically successful, and profitable innovations (2)	Carrier branches and other leading branches (3)	Core inputs and other key inputs (4)	Transport and communication infrastructure (5)	Managerial and organisational changes (6)	Appr. Upswing (booming) / Downswing (crisis of adjustment)(7)
1. Water-powered mechanisation of industry	Arkwright's Cromford mill (1771) Henry Cort's 'puddling'process (1784)	Cotton spinning Iron products Water wheelers Bleach	Iron Raw cotton Coal	Canals Turnpike roads Sailing ships	Factory systems Entrepreneurs Partnerships	1780-1815 / 1815-1848
2. Steam-powered mechanisation of industry and transport	Liverpool-Manchester Railway (1831) and Brunel's Great Western Atlantic Steam ship (1838)	Railways and equipment Steam engines Machine tools Alkali industries	Iron Coal	Railways Telegraph Steam ships	Join stock companies Subcontracting to responsible craft workers	1848-1873 / 1873-1895
3. Electrification of industry, transport and houses	Carnegie's Bessemer steel rail plant (1875) Edison's Electric Power Station NY (1882)	Electrical equipment Heavy engineering Heavy chemicals Steel products	Steel Copper Metal alloys	Steel railways Steel ships Telephone	Join stock companies Subcontracting to responsible craft workers	1895-1918 / 1918-1940
4. Motorisation of transport, civil and war economy	Ford's Highland Park assembly line (1913) Burton process for cracking heavy oil (1913)	Automobiles Trucks Tractors, Tanks Diesel engines Aircrafts Refineries	Oil Gas Synthetic materials	Radio Motorways Airports Airlines	Mass production and consumption Fordism Hierarchies	1941-1973 /
5. Computerisation of entire economy	IBM 1401 and 360 series (1960) Intel microprocessor (1972)	Computers Software ICT Biotechnology	Chips' (integrated circuits)	Information-highways	Networks ;internal, local and global Flexible specialisation	1973-???

Source: Freeman, and Soete,1997

After the new technoeconomic paradigm dominates, it develops beneath a new trajectory. Even though technological diversity grows rapidly as a result of the technological revolution, the productivity increase that will appear among the sectors based on the newly emerging technologies has a limit. As long as the possibilities of the new technological paradigm are consumed, profits will fall one by one as the sectors will come down to the level of growth and productivity increase speed will slow down (Taymaz 1993:15). Loss of productivity by the current paradigm will push economy toward the search of a new paradigm and the system will transit to a new technological paradigm. According to the neo-Schumpeterian approach, capitalist development process consists of five Kondratieff waves whose stylized facts are summarized in Table 2. Paradigm transitions have impact on the developing countries' industrialization dynamics. In the period in which the current technoeconomic paradigm is stable, corporate constructs will contribute to the development of the system harmonious with the dominant technological structure.

Capitalist development's stagnation depending on the technology matured within the current techno economic paradigm will cause that a long- wave will enter a regression path decreasing the profit ratios. In the regression stage of the long wave, financialization appears as a historical resort with the purpose of getting rid of the tendency of stagnancy encountered in economy. In this financialization period, in order to overcome the structural stagnancy by means of financial speculation and indebtedness, partial demand expansions are created. These demand expansion waves bring about problems as it is unable to constitute a sustainable growth. These problems expand toward high unemployment, incomplete employment, frequently encountered recessions, collapse of the stock exchange, and deflation. Deepening of the crisis will ensure the transformation of a technological system for the commencement of new increase waves. With the 2008 global crisis, the debates regarding the structural roots of the crisis brought the fact that whether we are in the beginning of a new Kondratieff wave into the agenda of the economical arguments. In this context, the impacts of the crisis, the future of the manufacture industry, and whether a re-growth trend based on new technologies exists or not have become an important subject of debate. Another matter of debate is about the countries that might make use of the opportunity windows that will be opened in such a technological paradigm transition period.

Hence, in the following section, the opportunity windows opened by the techno economic paradigm changes and the situation of the countries that made use of it in the transition period before the opportunity (microelectronic revolution) and that are referred to as the Asian Tigers will be briefly presented and their position within the current paradigm change process will be scrutinized in comparison with the Europe Union and other developed countries.

4. Sixth Kondratieff Debates: Nanotechnology and Future of Manufacture Industry:

Nanotechnology, one of the generic technologies at beginning sixth Kondratieff, has great potential for economic growth. Some authors has suggested that the nanotechnologies will be part of the next technological revolution because they have the potential to create big changes in technologies, products and industries, with social and economical implications to long term (Pérez, 2002).Few new technologies have been accompanied by such expansive promises of their potential to change the world as nanotechnology (Wonglimpiyarat, 2005). Nanotechnology has important implications for most sectors namely medicine, information, energy, materials, manufacturing, instrumentation, food, water, the environment and security as key areas (Kostoff et al. 2007).Nanotechnology presents a new revolutionist approach in the fundamental researches. (Wonglimpiyarat, 2005; Nefidow 2002) Investment on the technologies in nano-scale will drive the technological conventionalization defined in macro and micro levels toward the nano-systems. A new paradigm change will reveal the requirement that the old systems must be designed again as a whole. In order to create a sustainable and information-based industry system, it will be obligatory to create a nanoscience-based new research paradigm. Even though nanotechnology is principally similar with molecular manufacture, it is an applied science focusing on studying the innovations of the nano-dimensional matters resulting from the dimension-based phenomena (Roco 2003). Nanotechnology is related with the real-life implementations of the findings of nanoscience Nanotechnology's impact is so widespread that an excessively absolute definition can be illustrated in the manner that its actual scope is not realistic. Nanotechnology is the total of multiple technologies, processes, and techniques rather than a specific field of science or engineering (Roure, 2013).

The fact that nanotechnology is an interdisciplinary science and its domination of the different areas brought together the cooperation of the scientists from different disciplines and has the potential to impact many areas fundamentally in view of its outcomes.[2] In the forthcoming years, indispensableness of nanotechnology for many fields will be understood better. The added value that will be obtained especially in health, defense, textiles, energy, electronics, and photonics will take part in the market of high products and are expected to pave the way for new sectors (Roco, 2005).

Countries' industries will rise on the technologies and products that are obtained as a result of the rapid nanotechnology researches. In the nanotechnology field, biggest investment in the world is made by the USA. In the USA, national nanotechnology investment was 710 million dollars for 2003, which was increased to 850 million dollars for the first half of 2005. The US is followed by Japan with 650 million dollars and the European Union with 400 million dollars. Nanotechnology has become a sector that is growing in the entire world like an avalanche. In this field, presently 20 thousand researchers are studying worldwide. According to the estimations of the American National Science Academy, the number of the workers who will be working in the nanotechnology production sector in the forthcoming 15 years will be 2 million. The fact that nanotechnology is in the early stage creates substantial growth potential for the countries that will produce and develop this technology (Perez and Dominique 2008).

[2]The first name who attracts attentions in this regard is Richard Feynman who received Nobel Physics Award in 1965 thanks to his studies in the fields of quantum electrodynamics and the physics of the elementary particles. Richard Feynman says "There is plenty of room at the bottom" in his speech he gave in 1959 in California Institute of Technology, and calls attentions to atomic engineering.

Table 4: Transition between the two Predominant phases in Nanotechnology Development, 2000-2020

Interval	**2001-2010 ("Nano 1")**	**2011-2020 ("Nano 2")**
Measurements	Indirect, using time and volume averaging approaches	Direct, with atomic precision in the biological or engineering domains, and femtosecond resolution
Phenomena	Discovery of individual phenomena and nanostructures	Complex simultaneous phenomena; nanoscale integration
New R&D paradigms	Multidisciplinary discovery from the nanoscale	Focus on new performance; new domains of application; an increased focus on innovation
Synthesis and manufacturing processes	Empirical/semi-empirical; dominant: top-down miniaturization; nanoscale components; polymers and hard materials	Science-based design; increasing molecular bottom up assembly; nanoscale systems; increasingly biobased processes
Products	Improved existing products by using nanocomponents	Revolutionary new products enabled by creation of new systems; increasing bio-medical focus
Technology	From fragmented domains to cross-sector clusters	Toward emerging and converging technologies
Nanoscience and engineering penetration into new technologies	Advanced materials, electronics, chemicals, and pharmaceuticals	Increasing to: nanobiotechnology, energy resources, water resources, food and agriculture, forestry, simulation-based design methods; cognitive technologies
Education	From micro- to nanoscale based	Reversing the pyramid of learning by earlier learning of general nanotechnology concepts (Roco 2003b)
Societal impact	Ethical and EHS issues	Mass application; expanding sustainability, productivity, and health; socio-economic effects
Governance	Establish new methods; science-centric ecosystem	User-centric ecosystem; increasingly participatory; techno-socio-economic approach
International	Form al S&T community; establish nomenclature, patent, and standards organizations	Global implications for economy, balance of forces, environment, sustainability

Source: Roco, 2011:433

Nanotechnology's evolution as a technologic system is presented in the Table 4. While the 2001 -2010 period marks a period in which nanotechnology is used more indirectly, it is seen that its use for improving the current products and processes is widespread also in this period.

In the period that started subsequent to 2011, we witness that nanotechnology has transcendent the improvement of current product process or industries and started to create new product processes and industries. In this period, the transforming impact of nanotechnology on the industry is gradually increasing (Roco, 2011:433).

When the basic indicators are reviewed about nanotechnology in Table 5, it is seen that the US is the banner-bearer in terms of this technology. And a significant growth in every indicator appears to have been realized from the scrutiny of the basic indicators of the technology in the 2000-2008 periods. The biggest growth takes place in the R&D investments in this technology field and in the patents received (Roco, 2011:429).

Table 5: Six Key Indicators of Nanotechnology Development in the World and the US

World (USA)	People primary workforce	SCI papers	Patent applications	Final products market (Billion)	R&D funding public + private (Billion)	Venture capital (Billion)
2000 (actual)	~60,000 (25,000)	~18,085 (5,342)	~1,197 (405)	~$30 B ($13 B)	~$1.2 B ($0.37 B)	~0.21 B ($0.17 B)
2008 (actual)	~400,00 (150,000)	~65,000 (15,000)	~12,776 (3,729)	~$200 B ($80 B)	~$15 B ($3.7 B)	~$1.4 B ($1.17 B)
2000-2008 (average growth)	~25%	~23%	~35%	~25%	~35%	~30%
2015 (2000 estimate)	~2,000,000 (800,000)			~1,000 B ($400 B)		
2020 (extrapolation)	~6,000,000 (2,000,000)			~$3,000 B ($1,000 B)		

Source: Roco, 2011:429

In the evaluation of the countries' current statuses in terms of the issue nanotechnology, clear superiority of the developed country groups stand out. In the Table 6, Nanotechnology R&D expenditures in the business sector are presented. According to the data given in the table, the countries that spent most for R&D are the US, Germany, Japan, and Russia. Mexico and South Africa, which will be evaluated within the developing countries category, are the countries that make investment on nanotechnology as well. Belgium, Italy, Switzerland, and Czech Republic within the European Union are also conducting research and development activities.

Table 6: Nanotechnology R&D Expenditures in the Business Sector (2011 or latest Available Year)

	Total nanotechnology R&D expenditures, Millions USD PPP	Year	Nanotech R&D as a percentage of Business Enterprise Expenditure on R&D
Unites States	13.500,0	2010	4,8
Germany	1.549,3	2010	2,7
Japan	874,7	2011	0,8
France	726,9	2010	2,3
Russian Federation	711,4	2011	3,5
Italy	233,2	2010	1,8
Belgium	160,0	2011	2,7
Switzerland	156,3	2008	2,0
Mexico	122,8	2011	4,6
Ireland	51,4	2011	2,3
Czech Republic	48,5	2011	1,6
South Africa	31,7	2009	1,4
Denmark	22,8	2011	0,5
Norway	22,6	2011	0,9
Slovenia	11,1	2011	1,1
Portugal	4,2	2010	0,2
Slovak Republic	2,3	2011	0,7

Source: OECD, Key Nanotechnology Indicators,

In the Table 7, the number of firms active in nanotechnology is presented**.** The countries where the nanotechnology firms are most intense are the US, Germany, France, Japan, and Switzerland. These countries are also spearheading in terms of the number of the dedicated nanotechnology firms. The USA and Germany, France, Switzerland, Italy Belgium, and Denmark in the European Union and specifically Japan in Asia seem to be the countries that have succeeded to establish nanotechnology -based business sector.

Table 7: Number of Firm Active in Nanotechnology, (2011 or latest available year)

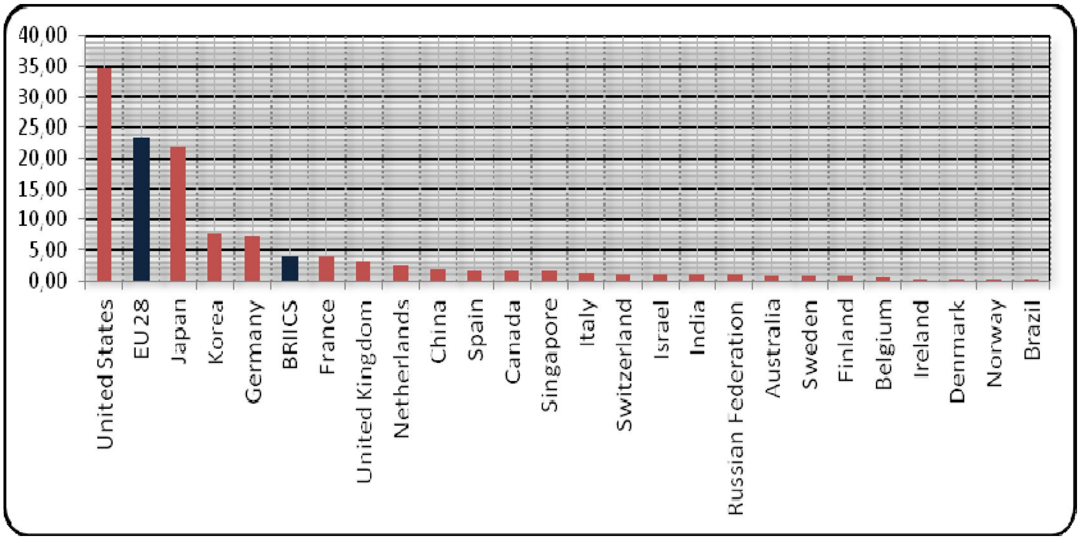
	Nanotechnology firms*	Dedicated nanotechnology firms**	% dedicated
United States	4.928	575	12%
Germany	960	250	26%
France	524	108	21%
Switzerland	222	65	29%
Japan	210	..	..
Mexico	188	..	..
Italy	157	47	30%
Belgium	125	14	11%
Ireland	79	..	..
Czech Republic	74	27	36%
Norway	63	..	..
Denmark	51	4	8%
Portugal	28	1	4%
Slovenia	11	3	27%
South Africa	10	0	0%
Slovak Republic	5	3	60%

*Nanotechnology firms use nanotechnology to produce goods or services and/or to perform nanotechnology R&D. **Dedicated nanotechnology firms devote at least 75% of their production of goods and services, or R&D, to nanotechnology.

Source: OECD, Key Nanotechnology Indicators,

In the Figure 1, share of the countries in nanotechnology patents filed under PCT are presented. When examined in terms of the countries and country groups, the USA is by far superior in regards to nanotechnology patents. In terms of the country groups, the European Union is listed second. Within the European Union, the leading country in terms of the nanotechnology patents is Germany. Within the Asian countries, Japan and S Korea are the countries that stand out. The countries group referred to as the BRICS (Brazil, Russia, India, China, and South Africa) Countries is rated five in terms of the number of the patents. Within the European Union, the countries producing technology in the field of nanotechnology after Germany are France, the United Kingdom, and the Netherlands. Among the developing countries, China is the leading country in regards to the number of the nanotechnology patents.

Figure 1: Share of Countries in Nanotechnology Patents Filed Under PCT, (2008-10)

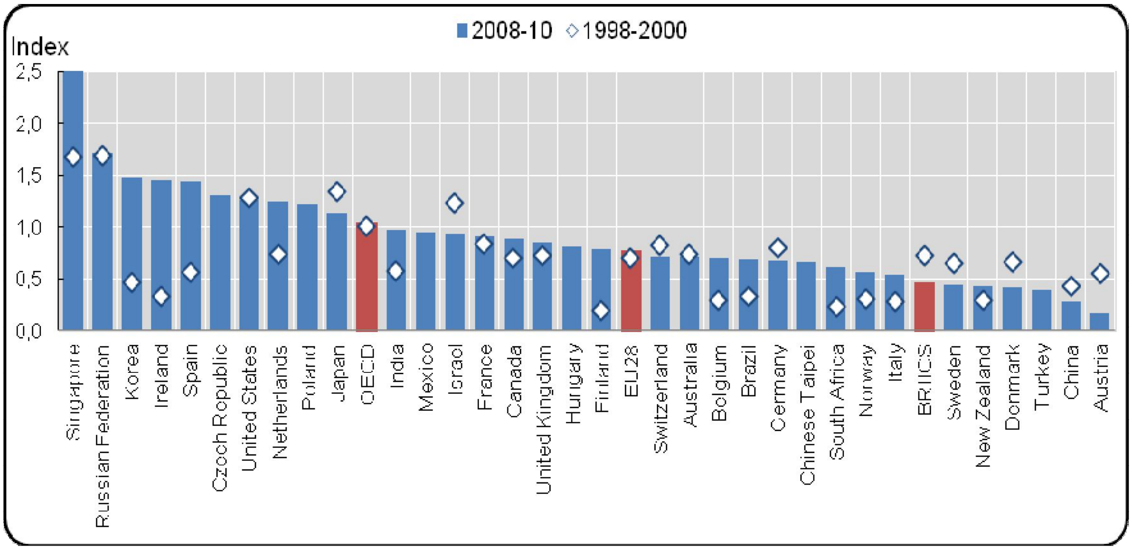


Source: OECD, Key Nanotechnology Indicators

In the Figure 2, "Revealed Technological Advantage" in nanotechnologies is presented. Thanks to the help of an index, technological advantages of countries in nanotechnology and the relative change of these advantages are presented for the 1998-2000 and 2008 -2010 periods. According to the results of this index, within the meaning of the country groups, OECD countries and the European Union countries are protecting their nanotechnology advantage they obtained in 1998 to 2000. BRICS countries seem to have lost their advantage they had in the 1998-2000 period. On country level, the Asian countries like Singapore and S.Korea and the European countries like Ireland, Spain, Norway, Italy, Finland, and the Netherlands increased their nanotechnology advantage, compared to the previous year. The countries like Japan, Israel, Denmark, and China seem to have lost their technological advantages compared to the 1998 - 2000 period. The USA, Germany, and Russia have protected their technology superiority in terms of nanotechnology. It is attention inviting that the countries exhibiting most development between the two sub-periods compared are the countries referred to as the Asian Tigers, such as Korea and Singapore, and Spain, Ireland, Belgium, and Finland. Being within the developing countries category, South Africa and Brazil have become the countries that are developing their technological advantage.

Outcome appears that the fact that the technological advantage of these countries that are among the BRICS (Brazil, Russia, India, China and S. Africa) countries has been developed stems from the relative recession of the superiority of the BRICS countries as a whole and from the decrease of technology investments in China and India.

Figure 2: Revealed Technological Advantage in Nanotechnologies, (1998-2000 and 2008-10)



Source: OECD, Key Nanotechnology Indicators,

On the subject of nanotechnology, having a role of technological superiority depends on imposed national scale state policies on technology based development. Taking these national programs aimed for the nanotechnology area very dedicatedly starting with a budget is extremely important. There are national research programs in the countries that make technological effort on the topic of nanotechnology. Instead of imposing a specific nanotechnology development program European Union specially places this technology within the Framework Program. However, within the European Union Germany and France implement specific national programs aimed for nanotechnology. USA as a pioneer country on this technology established a special program called “National Nanotechnology Initiative”. Brazil and India as a developing countries have special program for nanotechnology as well.

Table 8: Accountability for Public Spending in Nanotechnology towards a Responsible R&D Scheme

Country	Funding Programs	Nano-Specific?	Value
Brazil	Ministry for Science & Technology	No	R$11.87 million (€4.9 million)
China	Medium & Long Term Development Plan	Yes	US$38.2 million (€29.1 million)
European Union	Framework Program	No	€3.5 billion
France	Nano 2012 Program	Yes	€500 million
Germany	Nano Initiative – Action Plan 2010	Yes	€370 million
India	Nano Mission	Yes	Rs. 1000 crore (€144.8 million)
Japan	MEXT	No	€470 million
Russia	Development of nanotechnology infrastructure in the Russian Federation for 2008-2011	Yes	€693.3 million
UK	Research Councils UK/Technology Strategy Board	No	€256 million
USA	National Nanotechnology Initiative	Yes	$2.1 billion (€1.6 billion)

Source: Roure, 2013

In the period when world industrial production has shifted from west to east in order to attain the objective of re-industrialization which has been proclaimed by European Commission in 2011, Europe should base their industrial infrastructure on the new technologies particularly on nanotechnology. Asia's first generation of late industrialized countries (Asian Tigers) that well evaluated opportunities opened by techno-economic paradigm's process of change in the end of 1970s, which is Fifth Kondratieff's period of rise, knew how to get out enriched. Nowadays industrialized Asian countries like S. Korea, Taiwan, Singapore and particularly Japan using their opportunity utilization experience value a lot investment in technology based researches. The research facilities of Asian countries in nanotechnology were summarized in Table 9

Table 9: Nanotechnology Research and Policies in Asian Countries

Country	Research policies and activities
Thailand	Research activities in the field of nanotechnology are intended to respond to scientific and technological needs of Thai government's policy. The National Nanotechnology (Nanotech) is set up with an aim to increase Thailand's competitiveness. The R&D areas of focus include advanced polymer, nanocarbon, nanoglass, nanometal, nanoparticles, nanocoating, nanosynthesis with applications to the industries of automotive, food, energy, environment, medicine and health
Malaysia	The Malaysian government sets aside, under the eighth Malaysian Plan, USD 8 million for research in nanotechnology and precision engineering technology. The research projects in focus are nanophysics and nanochemistry. Malaysia currently invests in high-costlaboratories to incubate and develop new technologies, in an attempt to shift from a traditional manufacturing and assembly base into nano-R&D.
Singapore	Singapore's government policy in nanotechnology promotion is focussed on disk storage and biological fields. In 2002, the National University of Singapore Nanoscience and Nanotechnology Initiative (NUSNNI) was established as an interdisciplinary group to accelerate nanotechnology business.
China	The Chinese policy involved 'Climbing Project on Nanometer Science' (1990–1999). China has budgeted USD 240 million in less than five years from the central government and approximately USD 240–360 million from local governments for nanotechnology research. The areas of strength are development of nanoprobes and manufacturing processes using nanotubes.
Korea	The Korean government formulated the 'Comprehensive Plan for Nanotechnology Development' in 2001. It also launched a National Nanotechnology Program covering various fields whereby nanomaterials is one of the key research areas. The research projects are funded jointly by the government and the private sector. Major funding agencies are the Ministry of Science and Technology, the Ministry of commerce, Industry, and Energy. The research programs funded by the Ministry of Science and Technology are mostlybasic nanotechnology while the Ministry of Commerce, Industry, and Energy supports the research programs close to commercialisation
Taiwan	Taiwan launched the National S&T Priority Program on Nanotechnology in Taiwan (NPNT) with a budget of USD 680 million for research in nanotechnology. The implementing mechanism of fund allocation is according to a 20C/60/20-rule, with (1) 20% of the funding to be targeted towards nanotechnology with short-term commercial potentials, particularly those help upgradethe competitiveness of the traditional industries, (2) 60% of the R&D resources to be invested in the fields that will impact future competitiveness of current Taiwan hi-tech industries, (3) 20% of the project to be concentrated on the exploratory studies for potential applications that will generate innovative and new technologies.
Japan	Nanotechnology is ranked as an important field in the Second Science and Technology Basic Plan of the Japanese government. In 2002, the Japanese government announced the promotion of the 'New Industry Development Strategy' to tie nanotechnology and material science with new industries. Japan views the development of nanotechnology as the key to restoring its economy. In addition to government sponsored R&D, large corporations—Hitachi, Sony, Toray, Mitsubishi, Fujitsu, and Mitsui have invested in nanotechnology research.

Source: Wonglimpiyarat, 2005:135

On the other hand, as the last debt crisis in the European Union revealed, based on industrial production between the northern industry decline and southern structural problems are seen as the biggest obstacles in front of the goal of re-industrialization. Research development activities as well as implemented by European Union framework programs are promoted. However, there is no particular united technology program for nanotechnology in EU. Especially Germany and France, within the European Union, promote research activities on the subject of nanotechnology. After these countries, Netherlands, Finland, Belgium, Spain are the countries that invest in nanotechnology. If Europe wants to be competitive in industry on a global scale again, then it has to promote research development activities needed for new technologies.

5. Conclusion

It is observed that the world is in a global technological revolution process relying on the developments in biotechnology, nanotechnology, material and information technologies. New areas that will be brought about by these generic technologies can be exemplified as cheap solar energy, rural wireless communications, wearable computers, quantum cryptography, hybrid vehicles, improved diagnostic and surgical methods, and green manufacturing. These new technologies will change the production methods and manufactured products in many manufacture industry fields. The countries that will benefit from a sustainable growth depending upon the manufacture industry's production will be the countries with the skills of producing, utilizing, and adapting these new technologies. Within the scope of this study, first the long wave theory for the capitalist development was scrutinized through a neo-Schumpeterian perspective and the phenomenon of technoeconomic paradigm change was handled. Analyses regarding the fact that the phenomenon of big and deepening stagnancy experienced in the 2008 is the harbinger of the end of the current Kondratieff wave and the start of the sixth Kondratieff wave were presented and it was stated that the new growth waves will appear in connection with the generic technologies, specifically nanotechnology.

The change that will be created by the nanotechnology revolution on the near future of the humanity can only be estimated in its essentials.

It seems that nanotechnology will leave its mark on the civilization in a few forthcoming decades and, through such developments, difference between the weak and the strong countries will increase. Nanoscience and nanotechnology are entering our lives rapidly in many different fields. This impact starts with informatics and communication and extends toward the defense industry, space and aircraft technologies, and even the molecular biology and genetic engineering. Substantial and surprising outputs and new markets are expected from nanotechnology in the forthcoming 10 to 15 years. It is expressly observed that hundreds of nanotechnology research centers and departments at the universities are being established in Europe, the USA, and Japan and the expert staff is producing information and technology for primarily the national interests and then commercial interests in a race atmosphere in these centers. With nanotechnology, the gap between the developed countries and the undeveloped countries will grow bigger and bigger in the manner that it will not be closed again and the countries owning nanotechnology will become stronger in terms of the level of wealth, national defense, and economy. Within the scope of the study, the relative positions of the enriching Asian countries and European Union countries in regards to nanotechnology were comparatively examined making use of the previous technoeconomic paradigm (so called microelectronic revolution) change.

In this study a conclusion that, apart from these two country groups, especially the USA and Japan have technological superiority in terms of nanotechnology, was reached. In this context, it seems difficult to catch the nanotechnology train for the countries that were unable to catch the industrial and microelectronic revolution in a timely manner. Ability to seize this opportunity will only be possible by nationally empowering the expert staff, by providing education, and by paving the way for the technological accumulation that will be transferred from one generation to other. Hence, the countries that are able to make use of the opportunity window that will be opened within this technoeconomic paradigm transformation period appear to be the US, Germany, France, Japan, S Korea, and Singapore that made a long way in case of nanotechnology. Among the developing countries, especially China is endeavoring significantly in terms of obtaining a technological capability for nanotechnology. Thailand and Malaysia that are accepted as the second generation newly industrializing Asian countries are implementing different national projects in regards to nanotechnology. On the other hand, South Africa and Brazil are trying to make investments on this technology even though these investments capacity are limited. The country that is readiest in such a technological revolution appears to be the USA that is highly advanced in every measure.

Within the European Union, the spearheading country is Germany that has specifically a competitive manufacture industry. Germany, the production and export base of the European Union, is also the leader in this field of technology as well. Within Europe, the Netherlands, France, Belgium, Italy, and Finland are continuing their research and investment activities in terms of nanotechnology. Korea, Taiwan, Singapore, which made use of the previous technoeconomic paradigm change successfully, appear to be preparing well within this technological revolution. The European Union's re- industrialization program will be able to make the dream of a globally competitive Europe only if it is based on these new technologies. In the European Union, Germany, the trailblazer of industrial production, is the leading country in terms of nanotechnology and the European Union's southern countries (Spain, Italy, Portugal, and Greece) that incurred a debt crisis especially during the 2008 stagnation will have to create a nanotechnology-based industrial structure to reestablish their competitive power and disempowered industries. If the European Union fails to realize this transformation, it seems extremely difficult that it can continue its competitive position against the Asian economies, primarily S Korea, Japan and China.

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