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Leadership-driven innovation & evolution of societies

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LEADERSHIP-DRIVEN INNOVATION & EVOLUTION OF SOCIETIES

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The fundamental problem in the field of the economics of innovation is which economic subjects are the sources of radical innovations and high technological performances. The study here confronts this problem by developing a theoretical framework underpinned in the concept of purposeful system having a purpose of global leadership, which endeavours to analyse the sources of General-Purpose Technologies (GPTs) in a Schumpeterian world of innovation-based competition. Through an inductive study based on some societies that in the history have generated technological and economic change (Roman and Britain Empire, and current USA), the analysis shows vital characteristics that can be the sources of changes in the techno-economic paradigm. In particular, purposeful country-systems with high economic military potential, supported by a strategy of high R&D expenditures, and the objective of global leadership, winning international conflicts against other great powers (a very strong competition for the hegemony), tend to generate several inventions and radical innovations that are spread, in the long run, across wide geo-economic areas. It seems that the initial sources of GPTs (*e.g.* aqueduct, steam engine, jet aircraft, computer, etc.) are, *de facto,* associated with the global posture of great powers to achieve/sustain global leadership in intensive (effective and/or potential) international competitions, rather than warfare *per se.* This study refers to this nexus as *leadership-driven innovation*. International conflict is the context that spurs the GPTs, which are driven by global leadership of critical societies, whereas initial military R&D, demand and procurement are important mechanisms underlying the process that induces emerging path-breaking technologies. The vital linkages between observed facts can support a general socio-economic framework of the sources of path-breaking innovations based on a *leadership* of main economic subjects that support innovative activity (mainly in communications and energy systems parallel to transportation technology) and the evolution and development of human societies.

Keywords: Technological Innovation; Technological Change; Technological Paradigms; General-Purpose Technologies; Economic Change; Systems Concepts; Conflict; War; Global leadership; Great Powers, Techno-Economic Paradigm, Radical Innovation.

JEL classification: O31; O39; O10; N00; N31; N33.

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"*If economics wants to take technology seriously, economics will have to become a more historical discipline*"
Wright (1997, p. 1565)

Problem

Ayres (1998) claims that economic growth is a consequence of technological innovations, especially radical innovations (*cf.* Rae, 1834). In the field of the economics of innovation it is important to understand the sources of technical change that support economic growth and the wealth of nations (Rae, 1834; Sahal, 1981; Dosi, 1988; Freeman and Soete, 1987; Dixon, 1997; Silverberg and Soete, 1994; Freeman, 1994; Ruttan, 2001; Coccia, 2005b). In particular, the fundamental problem is to understand which countries, firms and other economic subjects are most likely to be the sources of radical innovations (Colombo *et al.,* 2014). The study here confronts this scientific issue by developing a conceptual framework of leadership-driven innovation, which endeavours to analyse the sources of new techno-economic paradigms, such as General-Purpose Technologies (GPTs)[2].

Some scholars have described several approaches to analyse the drivers of technological change (*cf.* Wright, 1997; Ruttan, 1997; 2006, pp. 8-14; Hall and Rosenberg, 2010). Porter and Stern (2001) show a positive relationship between Gross Domestic Product (GDP) per capita and innovative capacity of countries. Instead, Hayami and Ruttan (1985) discuss the process by which societies develop technologies that facilitate the substitution of relatively abundant (hence, cheap) factors of production for relatively scarce (hence, expensive) factors in the economic system: the hypothesis of induced innovation (*cf.* also Ruttan, 1997; 2001).

In general, technological change is driven by several concomitant forces that may coexist in a specific geo-economic places and timespan (Hall and Rosenberg, 2010; Coccia, 2009; 2010; 2012a, 2012; 2014, 2014a; 2014b; *cf. also* Seymour Lipset, 1959). However, the most impor-

[2] *See* Bresnahan and Trajtenberg, 1996; Bresnahan, 2010. This paper analyses the origins of GPTs that generate long-run structural and social change. These path-breaking innovations are mainly of transformative nature, which by a "destructive creation" (Calvano, 2007) makes prior products and knowledge obsolete (Colombo *et al.,* 2014). This study uses interchangeably the terms GPTs, disruptive technologies, radical innovations, revolutionary innovations, discontinuous innova-

tant driving force of changes in the techno-economic paradigm and GPTs is a fundamental problem for the economics of technical change, which is not well understood. Ruttan (1997, p. 1524) argues that: "approaches to understanding the sources of technical change – induced technical change, evolutionary theory, and path dependence – is approaching a dead end. Attempts to construct bridges linking the separate approaches are now necessary to advance our understanding of the sources of technical change."

This study develops a socio-economic theoretical framework based on the systems concept of purposeful country-system with the aim of global leadership to analyse vital common characteristics at the origins of path-breaking technologies and General-Purpose Technologies (GPTs), also called "Disruptive Technologies". This study is part of a large research programme *à la* Lakatos (1978) that aims to analyse the different sources of technological change to establish a comprehensive theoretical framework concerning the long-term development of new technology. The philosophy of science of this research is based on the position that there can be no adequate scientific knowledge where causes are unknown: "the cause of a phenomenon is whatever adequately explains it, the whole ground, reason, or source of it" (G. Vico as quoted by Flint, 1884, p. 105*ff*). This inductive study is performed by an approach of scientific realism based on an historical case study research and empirical evidence (Thagard, 1988, p. 145; *cf.* Kukla, 1998). The historical analyses constitute one main approach in the economics of innovation for supporting the development of a proper theoretical framework (David, 1985; 1997). In fact, Wright (1997, p. 1565) says: "if economics wants to take technology seriously, economics will have to become a more historical discipline".

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tions, new techno-economic paradigms and changes in the techno-economic paradigm to indicate path-breaking innovations with a very strong impact on geo-economic systems (Coccia, 2005; 2005a).

Background and Conceptual Grounding

General-Purpose Technologies (GPTs) are revolutionary changes from current technological trajectories (Bresnahan, 2010, pp. 763-791). GPTs are characterised by pervasiveness, inherent potential for technical improvements, and 'innovational complementarities', giving rise to increasing returns-to-scale such as the steam engine, the electric motor, and semiconductors (Bresnahan and Trajtenberg, 1996, p. 83, original emphasis, *cf.* also Lipsey *et al.,* 2005; Bresnahan, 2010). These path-breaking innovations exert a pervasive impact across firms, industries and socio-economic systems. Main features of GPTs are a long-run period between their emergence and their impact on socio-economic systems (David, 1990; Lipsey *et al.,* 1998; Rosenberg and Trajtenberg, 2004). The economic models (*e.g.* induced technical change, evolutionary theory and path dependence) provide substantial insight concerning characteristics, properties and rates of technological change, but they do not address the sources of path-breaking technologies (*cf.* Ruttan, 2006). As a matter of fact, the understanding of the sources of new techno-economic paradigms has not been accurately explored by economists of innovation (v. Tunzelmann *et al.* 2008, pp. 481-482; Teece, 2008, p. 510-511; Nelson, 2008, p. 496). Constant (1980, p. 15) advanced the concept of presumptive anomaly as sources of radical advances in technology: "presumptive anomaly occurs in technology . . . when assumptions derived from science indicate either under some future conditions the conventional system will fail (or function badly) or that a radically different system will do a better job" (*cf. also* Constant, 2000). However, a more comprehensive or general theory of the sources of GPTs does not yet exist (Ruttan, 2006).

According to Lundvall (1992), technological innovation is generated by a profitable interaction of elements within the national system of innovation[3] (*cf.* also Soete *et al.,* 2010; Nelson

[3] Lundvall (1992) states that the national system of innovation (NSI) refers to the complex network of agents, policies, and institutions supporting the process of technical advancement in an economy. The narrow definition of NSI includes the sub-system of research sector represented by universities and research laboratories, while the broad NSI includes many sub-systems such as finance, firms, government, research sector, and so on.

and Rosenberg, 1993). Soete *et al.* (2010, p. 1176) argue: "the notion of innovation systems points to a crucial role of history in contemporary economic performance, and the roots it has in innovation performance". However, a fruitful "National System of Innovation" is a necessary but not sufficient factor for supporting radical innovations and high technological performances by specific countries over time.

A vital role at the origin of path-breaking technological innovations (or "disruptive technologies") can be played by socio-economic shocks, such as warfare (*cf.* Ruttan, 2001; 2006; Mowery, 2010). Although the war is a major agent of change (Stein and Russett, 1980, p. 399), economists tend to exclude the war from theoretical explanations of phenomena and the war tends also to be a neglected explanatory variable in econometric modelling of innovation processes. Converse (1968, pp. 476-477) claims that: "for most . . . contributors once a war happens, it ceases to be interesting". As a matter of fact, economists mainly dealt with economic facts of a world "normally" at peace, whereas the relation between war and economic activity is mainly left to the historians (Mendershausen, 1943).

War is an activity to produce security and ensure the nation against foreign enemies. When a country passes from peace to war, structural changes occur in society's purposes and activities because international conflicts (wars and global wars in particular) influence negatively or positively some economic processes in a permanent way. A new main purpose of societies appears that of winning the war with vital socio-economic consequences (Mendershausen, 1943). In the Ancient period, the victory was decided by the strength and prowess of population, whereas the modern warfare depends more and more on drill, training, technical and engineering knowledge, mechanical-electronic and information skills, cyberpower (Kramer *et al.,* 2009), equipment and strategy, etc. Current international conflicts are won in research labs that generate high-teach weapons and systems (*cf.* Hirst, 1915, p. 3*ff*). In fact, economic analyses of the sources of technological change focused on peacetime economic activities can

be incomplete, and a better investigation of the war economy and mainly of war consequences can help to understand the general principles of the sources of technical change. In some studies of economics of innovation, social scientists have paid more attention to war's effects on technology (Ruttan, 2001; 2006; Mowery, 2010). Neurath (1919) showed the stimulating effect of war on technical and organisational progress. War can support not only technological innovations but also other types of innovations: *e.g.* income tax in England, a model applied in every country, is originated during Napoleonic wars under the need of restructuring the finance of the government for military requirements, as well as in London the metropolitan police has the root in this period of wars due to the necessity of public security for lacking of troops (*cf.* Gini, 1920, p. 205). In the US, during the Secession war, was established the federal set of rule about banks, which is the basis of current system. Main innovative reforms and actions of public interest are carried out during the war due to overriding needs. Hence, scholars can in-depth understand several socio-economic processes analysing the effects of wars and other forms of international conflicts (Stein and Russett, 1980, p. 400).

Social scholars have also a theoretical reluctance to differentiate between types of warfare and there is a tendency to treat the war as a generic phenomenon with equivalent socio-economic impact, whereas some wars are more important than others in terms of socio-economic effects and distribution of international power. In fact, there is a differential impact of different types of war/conflict and there is a distinctiveness of global warfare's impacts (Rasler and Thompson, 1985). In particular, the global wars (a specific typology of international conflicts) generate several socio-economic consequences and long-term structural changes (Stein and Russett, 1980, p. 401). Moreover, the effects of war on nation's capability depend on characteristics of the war and vary across major and minor powers.

A main role in international conflicts is played by leader countries (*e.g.* great powers) that have a high *economic war potential* based on a significant population (in terms of size, demo-

graphic, occupational and political structure), substantial raw material resources at the disposal, high technical level and economic organisation (Mendershausen, 1943, p. 8). In general, leaders of international conflicts have a better military capability, technological and economic superiority. Stein and Russett (1980) argue that the initial superior strength of some countries is provided by a superior military sophistication that can support the final victory.

The theoretical significance of international conflicts (a wide set that also includes global wars) has been underappreciated in the analyses to detect the sources of GPTs (Smith, 1985). International conflicts and wars tend to create significant impacts on socio-economic systems and changes in the national wealth and rates of growth. Some scholars have pointed out the role of the *demand side effects of wars* that spur a huge demand shock to economic system due to a massive increase in deficit spending and expansionary policy (*cf.* Field, 2008); the standard interpretation couples the demand effect with a powerful supply shock - *supply side effects* -, resulting from learning by doing in military production, spin-offs and spillovers from military R&D. These two main factors are the basis for asserting a substantial positive effect of military conflicts on potential output and productivity growth of some countries (*cf.* Alchian, 1963; Gemery and Hogendorn, 1993; Ruttan, 2006; Baumol, 1986, p. 1073). Ruttan (1997, p. 1524) claims that a general theory to understand the sources of technical change should link the induced and demand factors. The war seems responsible for establishing main technological, economic and infrastructural preconditions for an "age of high mass consumption" (Rostow, 1959, pp. 11-13). Wright (1997, p. 1565) examines the "American technological leadership" and shows that the post-war economic structure of the United States is mainly based on five industries: aircraft, electrical machinery, non-electrical machinery, chemicals and allied products, and motor vehicles (*cf. also* David, 1977; Rosenberg, 1992, pp. 66-69). These driving manufacturing sectors for US economy have taken advantages from fruitful

demand- and supply-side effects of war, amplified by vital advances in electronics and information technology.

Wars influence profoundly economic systems across space and over time. In particular, large (or global) wars constitute severe shocks to the economies of participants and neutral nations (Goldstein, 2003, p. 215). Technological development often follows military necessity in wartime. Governments can coordinate R&D investments to produce technologies for wars that can also be used for fruitful civilian technology in peacetime, such as the layouts of European railroad network were strongly influenced by military considerations, especially after Germany used railroads effectively to overwhelm French Force over 1870-71 period, radar technology developed during World War II, the commercial diffusion over 1990s of the global positioning system (GPS) created for US military purpose, etc. (Goldstein, 2003).

Wartime mobilisation leads to increased rate of inventions and technological innovations and, more importantly, to post war technological diffusion, both of which promote long-run economic growth (Stein and Russett, 1980, p. 412). However, Field (2008) argues less fruitful perspectives concerning the effects of the war.

Modelski (1972) claims that wars play a major role in the distribution of power in the international system (*cf.* Levy, 1983; 2011). As a matter of facts, wars can fundamentally change the international system by affecting the number of actors in the system and their relative power (Modelski, 1972, p. 418). Moreover, Modelski (1972, p. 48) asserts that "war causes the Great Powers" (*e.g.* Roman Empire in the 30 BC – 500 AD, Britain Empire in the 1710-1850, the USA from 1940s onwards, etc.), which shape the global-political and economic system (Stein and Russett, 1980).

Kindleberger (1989, p. 203) claims that:

> The Thirty Years' War from 1618 to 1648, culminating in the economic dominance of the Netherlands, the French revolutionary, and Napoleonic wars from 1792 to 1815, ending in

> Great Britain at the apex of the world economy, and the combined World Wars I and II, from 1914 to 1945 that led to the United States taking over as the world's leading economic power.

Several nations have lost their status of great power or imperial leader as result of wars (*e.g.* Austria-Hungary in 1918; Italy in 1944; Germany and Japan in 1945; *cf.* Stein and Russett, 1980). Major wars or large hegemonic wars among core countries produce changes in the global leadership of the world economy and "hegemonic cycles", which are not regular and tend to be longer, in average, than 150 years (Kindleberger, 1989, p. 203ff; *cf.* Kennedy, 1987, Cipolla, 1970; Olson, 1982).

Hence, countries with a high economic military potential, winning an international conflict, can achieve and/or sustain a global leadership or hegemony on wide geo-economic areas. Linstone (2007, p. 115) claims that: "the winner in each case became the leading global power, a new global political economy emerged, and democracy advanced" (*cf.* Devezas, 2006). The global leader tends to affect economic institutions and trade patterns of several geo-economic systems in subsequent peacetime and can support a social change of losers by a better social organisation of their institutions.

Empire or Great power can be considered: "large-scale political organizations that might usefully be studied as complex systems. But they are also products of their age, and must be examined in the context of their time and place" (Modelski, 2010, p. 1418). In fact, leading nations in the long run can also degenerate into functional inconsistencies and collapses such as the Roman Empire.

Modelski (2010, p. 1419) argues that:

> Empires are not the only form of large-scale political organization…. two other forms, global leadership (other terms used for it include hegemony – Greek for leadership – and global primacy), and . . . global organization. . . . (Britain) is a case of global leadership that toward the close of its trajectory exhibited imperial features. The United States, too, in relation to the world system, is an instance of global leadership. And global leadership can be seen as a transitional form evolving in the direction of enhanced global organization.

Ferguson (2010) also considers the Empires or Global Leaders as complex systems, organised on a wide territory, that have a continuous behaviour of adaptation to turbulent environments (*cf.* Linstone, 2010; Devezas, 2010, p. 1412*ff*). Ferguson (2010) notes that after the World War II, the U.S. assume the role of global leadership, replacing U.K. and "shifting from an informal to a formal empire much as late Victorian Britain once did" (as quoted by Modelski, 2010, p. 1419)[4]. As a matter of fact, Ferguson (2010) considers the posture of the United States similar to an Empire with a military, political, economic and technological leadership worldwide recognised. Instead, Modelski (2010, pp. 1419-1420, original emphasis) claims that the USA is network-based and oriented to long-distance trade: "inclining at times to the temptations of 'informal empire' but in its basically non-imperial organisation capable of responding flexibly to international crises. . . . its proper name is global leadership, an evolutionary, and therefore transitional form capable of adaptation and self-transformation in response to mounting global problems".

Current world is increasingly global, complex, turbulent, interconnected and multilevel, with wealthier countries than last two centuries, such that imperial aspirations are impracticable; the only feasible direction of countries with high economic potential is a global posture to achieve/sustain a leadership worldwide, reinforced over time with a higher economic and technological performances in comparison to other strong economic competitors (*cf.* Modelski, 2010, p. 1419*ff*).

This inductive study analyses, in a Schumpeterian world of innovation-based competition, the common characteristics and factors of the sources of GPTs governed by global posture to the leadership of some countries.

Method and study design

The study here considers the economic subjects (*e.g.* countries, firms, etc.) as complex

[4] *cf. also* Devezas and Modelski, 2003; Devezas, 2006; Ferguson, 2003.

systems, which by evolutionary processes of learning and adaptation, achieve specific purposes in a turbulent environment (*cf.* Modis, 2010; David and Rothwell,1996). The following fundamental systems concepts underpin the theoretical framework of this study.

> A *purposeful system* is one which can produce the same outcome in different ways in the same (internal or external) state and can produce different outcomes in the same and different states (Ackoff, 1971, p. 666, original emphasis)
> The *objective* of a purposeful system in a particular situation is a preferred outcome that cannot be obtained within a specified period but which can be obtained over a long time period
> (Ackoff, 1971, p. 667, original emphasis)
> Adaptiveness is the ability of a system to modify itself or its environment when either has changed to the system's disadvantage so as to regain at least some of its lost efficiency (Ackoff, 1971, p. 668)….To *learn* is to increase one's efficiency in the pursuit of a goal under unchanging conditions (Ackoff, 1971, p. 669, original emphasis).

In general, a leading country can be considered a purposeful system with several objectives: wealth, power, global leadership, comfort, national security or a combination of them. When one of this objective or multi-objective is achieved, institutions and, as a consequence, population are interested in its maintenance and extension to support long-run progress of the nation (Hirst, 1915).

This study focuses on a specific typology of conflict, the international and major conflict[5] that generates main structural change of economic systems; instead, normal conflicts/wars do not tend to produce social change and economic-wide effects.

Some main concepts for underpinning the sources of new techno-economic paradigms are:

Assumption 1 (*context*): International conflicts (such as global wars or challenges in "Big Science") are intensive competitions (military and not military) across great powers to achieve/sustain the global leadership and affect wide geo-economic areas.

Assumption 2: International conflicts cause a strong social impact and economy-wide effects in the long run.

Assumption 3 (*global leadership*): A purposeful country-system γ is a complex system with high economic war potential, significant capability and purposeful elements that have the common purpose of global leadership.

[5] Pay particular attention that conflicts may be military and not military ones.

Assumption 4 (*mechanisms*): A purposeful country-system γ implements evolutionary processes of learning and adaptation based on high military R&D (strategy θ) to achieve/sustain the global leadership by winning international conflicts.

The hypothetical approach is based on the following hypothesis α (*HPα*), which this study intends to validate.

- *Hypothesis α (HP α)* of *leadership-driven innovation*: A purposeful country-system γ, implementing strategies of learning and adaptation θ to win international conflicts and achieve the global leadership, is a driving force of radical technologies, GPTs or new techno-economic paradigms that are diffused in the long run on wide geo-economic areas.

The purpose of the present study is to ascertain whether the inductive approach, based on historical and statistical evidence, supports the hypothesis *HPα*.

Historical and statistical approaches

In order to validate the *HP*α, main purposeful systems γ with global leadership achieved by winning international conflicts against other hegemonic powers are analysed. This study focuses on global leaderships that have played a critical role in the worldwide technological progress and economic change: Roman and British Empire, and the USA.

In particular,

- For Roman Empire γ_1, the study considers the period from 214 Before Christ (B. C.) onwards, when Rome begins the conquest of the Mediterranean Sea Area and Europe.
- For British Empire γ_2, the study considers the period from Seven Years' War and Global conflict with France to achieve the hegemony.
- For the USA γ_3, the study considers the period from 1940s onwards when, after the victory of World War II, the US have been playing a leading role worldwide.

The timespan is equal to 74 years for these global leaders:

- for Roman Empire is from 214 to 140 B. C.
- for British Empire is from 1756 to 1830
- for the USA, 1940-2014 period

The study analyses these leading societies γ by some steps.

1. The *posture of global leadership* of these purposeful systems γ is detected by analysing some key documents and studies. The *purpose* of powerful country-systems is to achieve the global leadership to take advantage of important territorial opportunities and/or to cope with consequential environmental threats. The global posture and purpose of the purposeful system γ for achieving the world-wide leadership is detected considering the number of wars performed over a fixed period of time. This *modus operandi* of engaging international conflicts and/or wars can yield, by victories, a fruitful global leadership on wide geo-economic areas. The incumbent global leadership needs to be sustained over time in the presence of threats by other belligerent systems.
2. *The connection between global leadership and origins of new techno-economic paradigms.* This study analyses briefly the origins of some path-breaking technological innovations and General-Purpose Technologies (GPTs) within these societies γ with global leadership. In particular:

   - roads, aqueducts and water mills for the Roman Empire;
   - steam engine in the British Empire;
   - jet aircraft, computer and internet for the US Global leadership.

   These main new techno-economic paradigms generate a platform and infrastructure for supporting clusters of innovations and new technological trajectories. These GPTs induce huge advances in communications and energy systems that are parallel to development in transportation technologies with a very strong impact on wide geo-economic areas

(David, 1969; Soete, 2001; 2006; Coccia, 2005, p. 123; 2005a).

3. *Mechanisms underlying the origins of GPTs governed by global leader to achieve/sustain the global leadership.* The analysis of the *strategy* θ of the system γ for sustaining the global leadership can be measured and assessed by the levels of military expenditure as percentage of Gross Domestic Product (GDP)[6] in comparison to other main geo-political systems. The military R&D is important to support bases, active-duty personnel, operating costs, new military technology and other military activity to cope with (effective and/or potential) conflicts. The metrics based on military expenditures as % of GDP, of course, is applied only in the case of the USA, whereas for Roman Empire some reliable conjectures about the main role of military expenditures are based on historical facts concerning the total army forces (estimated), instead for British Empire information about the level of military R&D are deducted by number of soldiers and naval fleet of Royal Navy during key wartime.
4. *High technological performance to support global leadership*. In order to show that global leaders have also high technological performances in peacetime to support this incumbent role, the analysis of commercial technological outputs is performed by patents. Patents are the most common metrics of innovative outputs to analyse technological outputs of advanced societies (*cf.* Steil *et al.,* 2002, pp. 3-22; Coccia, 2010; Moser, 2013). In fact, innovations are protected by patents, which can indicate the current innovations of countries and also commercially promising inventions (*cf.* Coccia, 2010; Kortum, 1997). According to Hunt and Gauthier-Loiselle (2011, p. 32): "the purpose of studying patents is to gain insight into technological progress, a driver of productivity growth, and ultimately economic growth". This study uses as source of patents and other technological indicators, such as R&D intensity, data by World Bank (2008) for US case study. In par-

ticular, the statistical analysis shows main trends and arithmetic means of innovative structural indicators. The rates of growth of US patents in comparison to other geo-economic systems are computed by the *exponential* model of patent development:

${}_tP={}_0P \cdot e^{rt}$ where e is the base of natural logarithm (2.71828…)

$$\frac{{}_tP}{{}_0P} = e^{r\,t}\,;\;\; Log\,\frac{{}_tP}{{}_0P} = r \cdot t\,;\; r = \frac{Log\left(\frac{{}_tP}{{}_0P}\right)}{t}. \qquad [1]$$

where :

1: ${}_aP$ is patent applications of resident per million people at 1985 in the USA and High income OECD Countries[7]

2: ${}_tP$ is patent applications of resident per million people at 2005 in the USA and High income OECD Countries

3: $t = 20$ years

4: Political economy of R&D over Forecast horizon]$t+n$ onwards[(*e.g.* from 2005 onwards) is similar to [t; $t+n$], *i.e.* [1985. . . 2005] (period of available data).

Patents, as metrics of technological innovation, are applied only for assessing the commercial technological development of the USA, whereas for Roman Empire, this study performs some conjectures concerning inventions and innovations based on historical facts and studies. Instead, for British Empire, this study considers some results of historical researches based on patents of England during the Industrial Revolution by Bottomley (2007).

The inductive study, based on a case study research, endeavours to detect common characteristics and regularity at the origin of new techno-economic paradigms to lay the foundations for a theoretical framework concerning the sources of new techno-economic paradigms.

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[6] The gross domestic product (GDP)—the value of all goods and services produced minus the value of any goods or services used in their creation—is the most common metrics applied in socioeconomic studies to measure the economic activity and wealth of nations.

[7] The Organisation for Economic Co-operation and Development (OECD) Countries are: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States.

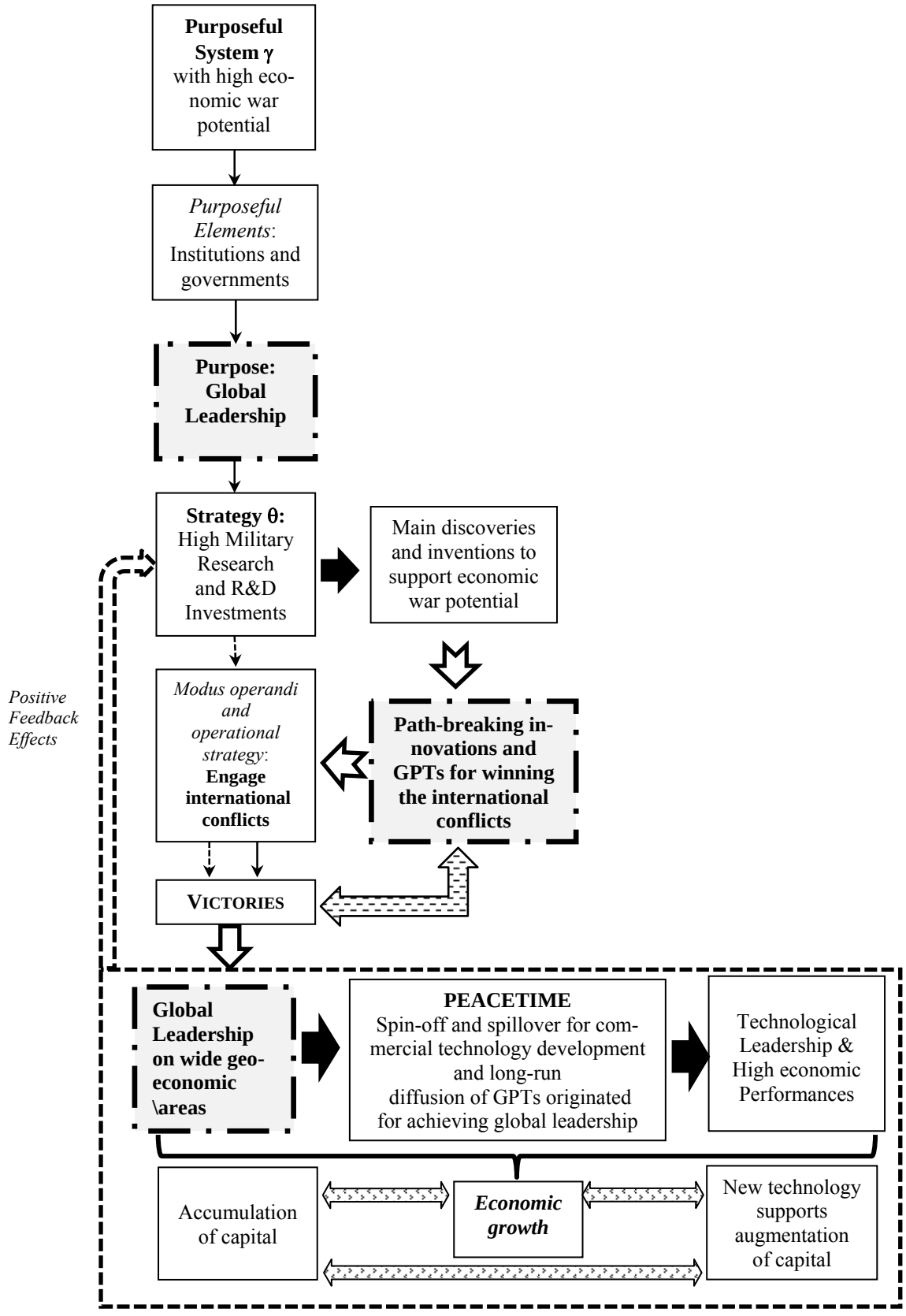

Figure 1. Flowchart from Global Leadership to the Origins of GPTs: Linkages and positive feedback effects of innovation process governed by purposeful systems γ for supporting global leadership and high technological and economic performances. *Note:* key boxes are in grey and dotted line.

In short, the study tends to support the hypothesis *HP α* that GPTs are associated with the role of country-systems γ, with high economic war potential and technological capability (*e.g.* Roman and British Empire, and the USA), to achieve/sustain a global leadership in turbulent environment. Figure 1 shows the linkages that underpin the conceptual framework, which endeavours to explain the sources of GPTs and high technological performances by country-systems γ with global leadership.

Evidence

■ *Global posture to the leadership*

- *Roman Empire: a global leader of the Ancient period*

The global posture of the Roman Empire, from several historical documents, is based on an attitude of Roman Emperors and Senate to achieve the domination of Mediterranean Sea geo-economic area and Europe. The Latin phrase *Imperium sine fine* ("Empire without end") expressed the ideology by Roman society that neither time nor space limited the Roman Empire (*cf.* Nicolet, 1991). The history shows that the global leadership by Rome established, roughly over 27BC-293AD, one of the largest Empire in history, with territories throughout Europe, North Africa, and the Middle East (Kelly, 2006).

- *British Empire and the global leadership*

The posture of the Kingdom of Great British to achieve the global leadership from 1710s can be detected by the high number of declarations of wars by George I, II, III; in particular 1718, 1739, 1762 and 1779 (against Spain); 1744, 1756, 1778 and 1803 (against France); 1780 (against Dutch Republic). The purpose was mainly commercial by acquiring foreign territories that were rich sources of raw materials in order to support and provide markets for British manufactures, increasing the exportations according to mercantilism theory (Canny, 1998; Ferguson, 2003; Abernethy, 2000; The Governance of Britain, 2007).

- *The United States of America and the ongoing global leadership*

Kindleberger (1989) argues that the USA, winning the World Wars I and II, over 1914-1945, have achieved the world's leading economic power and a global leadership world-wide recognised (*cf. also* Wright, 1943). Davis *et al.* (2012, p. 7) show the list of US enduring interests to sustain the global leadership such as: protect U.S. allies and partners from state adversaries; promote U.S. influence in key regions; respond to regional conflicts and ensure the flow of commerce and key resources.

■ *To achieve and sustain global leadership by engaging and winning international conflicts*

The *modus operandi* of the purposeful systems in the case study research for achieving and sustaining the global leadership is based on a proactive role to engage international conflicts. In order to support the HPα by critical evidence, Table 1 shows that the USA have engaged about 67 international conflicts over 1940-2014, whereas Roman Empire roughly 63 over 214-140B.C, British Empire 71 over 1756-1830. The global posture of these purposeful systems γ is prone to engage international conflicts, obtaining in the majority of cases victories that support the global leadership on wide geo-economic areas (*see* Table 2).

Table 1. Total years of international military conflicts for Roman and British Empire and the USA to achieve the global leadership

Roman Empire over 214-140BC (Before Christ)			British Empire over 1756 to 1830			The USA over 1940-2014		
YEARS B.C. for Rome	Total years in which Rome engaged wars*	%	YEARS for the Great Britain	Total years in which the Great Britain engaged warsξ	%	YEARS for the US	Total years in which the US engaged wars§	%
214-140	63	84%	1756 to 1830	71	94.7%	1940 - 2014	67	89%

Source: * (Liddell, 1864); § (Whiteclay Chambers, 1999; Allison *et al.* 2012; United States Senate, 2014). ξ (Laycock, 2012; Canny, 1998). The data may change according to historical sources analysed.
Note: this study considers a specific period of 74 years in which the great power has a clear posture to achieve/sustain the global leadership.

Table 2. Results of some international conflicts for Roman and British Empire, and The USA to achieve and sustain global leadership

Roman Empire over 214-140B.C. *			British Empire over 1756 to 1830ξ			The USA over 1940-2014 §		
Results Battles	*N.*	*%*	*Results Wars*	*N.*	*%*	*Results Wars*	*N.*	*%*
			Net	10				
Victories	88	62.41	Victories		28,57	Victories	23	53.49
Defeat	27	19.15	Net Defeat	4	11,43	Ceasefire	3	6.98
Undetermined	27	19.15	Treaty	18(1)	51,43	Withdraw	4	9.30
-			Stalemate	1	2,86	Agreement	1	2.33
			Peace	1	2,86	Undetermined	4	9.30
			Conventions	1	2,86	Ongoing	8	18.60
		100%			100			100%

Note: The results are approximately because can change according to historical sources analysed. In the past the wars were mainly performed by battles (pitched battle and/or naval combat). Now the strategy of warfare is changed due to new technology and based on naval, aircraft and missile attacks. *Source*: * (Cassio Dione, 1823); § (Allison *et al.,* 2012; Whiteclay Chambers, 1999); ξ (Laycock, 2012; Canny, 1998). (1) The Kingdom of Great Britain, after wars, agrees several Treaties in which acquired several territories due to the positive results of military conflicts (significant number of victories).

Figure 2. Western and Eastern Roman Empire (in red/orange colour) in the about 120 (*cf.* Liddel, 1864). *Source*: Utah State University -http://www.usu.edu/ by Damen 2013- accessed December 2013 (http://www.usu.edu/markdamen/1320Hist&Civ/chapters/08ROMFAL.htm)

Figure 2 shows a map of Provinces by Roman Empire and some reigns affected by Rome in the year 117. This figure 2 confirms the global leadership by Rome in the Ancient period, underpinned in a strong military, economic and political power, achieved and sustained by en-

gaging and winning several international conflicts over time. Figure 3 shows that posture of global leadership by British Empire with several geo-economic areas controlled over time.

Figure 3. Geo-economic areas controlled by the British Empire over time.
Source: http://en.wikipedia.org/wiki/File:The_British_Empire.png (accessed December 2014) Composed from maps found in: Brown (1998); Nigel (2006)

Figure 4. US Global leadership: military installations (in red/dark colour)
Source: U.S. DoD (2003)

Figure 4 displays a map of geographical areas where there are US installations[8] to sustain the ongoing global leadership. In particular, US Department of Defense (DoD) has about 700 foreign installations in more than 60 countries worldwide (DoD, 2003). Davis *et al.* (2012) claim:

> Since World War II, the United States has relied on a network of global military bases and forces to provide forward, collective defense against the Soviet Union, to counter the proliferation of weapons of mass destruction, and to fight terrorism (p. xiii) . . . .
> The current U.S. overseas military is largely the outcome of responses to threats as they emerged historically and over time, in Western Europe and in East Asia to the Soviet Union . . . . the Soviet Union has transitioned from a peer competitor to something less, while China's economic standing and military capabilities allow it increasingly to challenge U.S. global leadership (p. 1).

The high presence of US military installations in figure 4 shows the geo-political world-wide influence by US global leadership, achieved and sustained after World War II.

- *The strong connection between Global Leadership of Great Powers and new techno-economic paradigms*

The strategy and *modus operandi* of purposeful systems γ with global leadership seem to be a main driver of technological change. *Some* main GPTs originated by global leadership societies are as follows.

- *GPTs by Roman society (Roads, Aqueducts and Water Mills)*

The Roman Empire during its global leadership has originated and diffused vital GPTs in engineering and construction technology (*e.g.* roads, aqueducts, the use of bricks in construction technique, etc.) as well as water mills for the production of energy and the substitution of labour (Singer *et al.,* 1956). Rae (1834[1905], p. 168) argues: "The mechanical part of architecture underwent a revolution among the nations that were finally consolidated into the Roman Empire, by the adoption of the arch, and the employment of cement. The Egyptians and Grecians were stonecutters; the romans, masons".

The incentive to support main innovations was mainly driven by military objectives. In fact, the Romans primarily built roads for their military purposes to enhance transportation of stra-

[8] Installation: "A military base, camp, post, station, yard, center, homeport facility for any ship, or other activity under the jurisdiction of the

tegic materials and communications in the Empire. These GPTs (roads, bridges, etc.) have probably also a significant economic importance, though wagon traffic was often banned from the roads and bridges to preserve their strategic military value (Singer *et al.,* 1956, Ch. 14, vol. 2). These main GPTs, subsequently, in the long run, were also used for commercial activities.

The Romans also constructed numerous aqueducts (a vital GPTs in the advances of ancient societies) to supply water in several colonies. Roman aqueducts were built to remarkably fine tolerances and to a high technological standard. These main GPTs supported an efficient social organisation and development of Rome (Singer *et al.,* 1956, vol. 1). Moreover, the global posture and leadership by Roman Empire spread these GPTs across wide geo-economic areas, such as Spain, France, etc.

These GPTs created a platform that has spurred clusters of technological innovations. For instance, the mill was known at the time of Julius Caesar in Rome and the wide diffusion of this path-breaking innovation across the wide territory of the Roman Empire was supported by GPTs of the aqueducts, infrastructures that transported large amounts of water very efficiently (*cf.* Forbes, 1955-56). These vital new techno-economic paradigms (aqueducts and water mills) supply hydro-mechanical energy for the economy of the Roman Empire (Greene, 2000; Singer *et al.,* 1956). In fact, GPTs of the water mill were a means of employing the power of the water in the operation of grinding and other main economic activities, supporting the progress of the Roman society (Rae, 1834[1905] p. 178-179). Hence, global leadership by Rome generates and spreads vital GPTs that are main socio-economic platforms for supporting new technological trajectories and, as a consequence, the technological and economic progress of the Ancient world in wide geo-economic areas (*cf.* Rosenberg, 1992).

Department of Defense, including leased space, that is controlled by, or primarily supports DoD's activities" (U. S. DoD, 2003).

- *GPTs during Great Britain global leadership (Steam engine)*

Napoleonic wars from 1792 to 1815 (a main global war for the hegemony) led to the global leadership of the Great Britain (the British Empire), which subsequently affects the world economy. In fact, during this historical period of the British global leadership, Industrial Revolution is originated in England, driven by the GPTs of the steam engine and other radical innovations (*cf.* Rae, 1834). Ruttan (2006a, p. 3-4) argues that: "knowledge acquired in making weapons played an important role in the industrial revolution". These changes in the techno-economic paradigm during the global leadership of England are driven by steam engine and rapidly diffused towards other European countries and North America (now Canada and the USA), generating a huge economic and employment growth in several industries (Rae, 1834; Mokyr, 2010; *cf.* Novolari *et al.,* 2011).

- *GPTs during U.S. global leadership (Jet Aircraft, Computer and Internet)*

Modelski (2010, p. 1419) claims that: "It is widely recognized that in the 20th century, spurred by two world wars, the United States stepped into the role previously occupied by Britain". In fact, the United States, as ongoing global leader, are playing a predominant role in initiating or implementing new General-Purpose Technologies (GPTs) that have emerged from military and defense R&D, such as jet aircraft, computer, semiconductor, satellites, telecommunications technology, etc.

Ruttan (2006) and Mowery (2010) show that US military sector has supported the development of jet aircraft as a main new technology to have the pre-emption during international conflicts. In addition, intensive military procurement, subsequently, has improved the jet aircraft technology and supported the commercial development of groundbreaking products in the civilian aviation industry, such as Boing 707 and 747.

The first calculator was a military order by a US missile laboratory. The Korean War and Cold War against Russia have played a main role to develop the computer by IBM as a fully

transistorised commercial computer. Now these GPTs are generating a huge structural change across all industries and socio-economic systems (*cf.* Sahal, 1981; Ruttan, 2006; Mowery, 2010).

The development of internet has its origin in a computer network initially established in the 1960s with an advanced research projects agency (ARPA) by Defence department for having a strategic technology of telecommunications during the Cold war against Russia. The successful demonstration at the 1st international conference on computer communications held in October 1972 at Washington D. C. spurred the possible convergence of computer and telecommunications industries. Now the impressive effects of these GPTs are well known (*cf.* Devezas *et al.,* 2005).

These GPTs, originated to support global leadership in military settings, have had a pervasive diffusion in the peacetime and stable economies by exerting a very strong impact on world-wide growth of socio-economic systems with a "creative" substitution from old to new technology.

In particular global leadership tends to support the origin and pervasive diffusion of GPTs and new techno-economic paradigms with very strong long-run impact on wide geo-economic systems (*cf.* Soete, 1985; 2001). This inductive study seems to show a fruitful *nexus* from global leadership, underpinned in the high military R&D and economic war potential, to development of new path-breaking technology: *leadership-driven Innovation*.

- *Mechanisms underlying the purpose of achieving/sustaining global leadership that support the sources of GPTs: Military expenses and investments*

The *strategy* θ to achieve and sustain the global leadership by the purposeful system γ is underpinned in higher military research and expenditures to be more efficient in (effective and/or potential) international conflicts.

- For *Roman Empire* there are not reliable data about military research and expenditures. However, some historical documents confirm the high investments in human resources and military technology by Rome during several wars (Hugh, 1996; Grant, 1993). In fact, Roman society gave particular attention to the role of military technology in order to sustain the worldwide supremacy (*e.g.* some Roman military innovations such as ballista, gladius - short sword of the Roman army- provided critical strategic and tactical advantages during the continuous warfare-*cf.* Vegezio, 2001; Cassio Dione, 1823; Tito Livio, 2003; Urso, 2013).

Table 3. Roman Army 24–337BC

Roman Emperors	Tiberio	Traiano	Adriano	Marco Aurelio	Settimio Severo	Aureliano Military Anarchy	Diocleziano	Costantino I
Period AD	*24*	*107*	*ca. 135*	*166/7*	*211*	*275*	*305*	*337*
Total Roman Force (units)	300.000	454.000	443.000	454.000	502.000	524.000	584/599.500	645.000~
Other estimates *	255.000		383.000		442.000		390.000	410.000

Source: *Hassal (2000), MacMullen (1979), Elton (1996).

A main proxy of huge military investments for supporting Roman leadership can be detected by estimates of Roman Army forces per each Emperor (*see* Table *3; cf. also* Jones, 1986; Webster, 1998; Goldsworthy, 2000).

- For the *Kingdom of Great Britain* is difficult to find data about military expenditures, but some deductions of historical facts can provide a proxy of the main role of military in-

vestments (tab. 4). In particular, the military investments of the British Empire can be detected in the naval force. The Royal Navy grew from 173 ships (about 100,000tons) in 1688 to 755 ships (more than 500,000tons) in sea service in 1809 (Williamson, 2002; *cf.* Duffy, 1980; 1992). Moreover the Royal Navy heavily invested in the establishment of naval bases overseas. Another main factor that shows the high military investment by Britain to support the leadership is the expansion of war manpower in tab. 5.

Table 4. British Army over 1700s-1780s

Period of war	Troops
War of the Spanish Succession (1702-13)	In 1702, England has less than 20,000 soldiers (Paget, 1977; *cf.* Black, 1999), but this number is expanded greatly to support the war effort. Parliament approved enough funding to support 50,000 troops by 1706 and 75,000 by 1711 (Scouller, 1966).
Seven Years' War in 1762	The number of troops on British pay had peaked near the end of the Seven Years War, at about 230,000 including German mercenaries. The war had caused Britain great economic hardship, and these in turn brought drastic cutbacks to the Army.
The War of American Independence (1775-83)	The rebellion in the North American colonies, where an estimated 450,000 men were capable of fighting (250,000 different men were enlisted at one point or another for the American side) (*cf.* Barnett, 1970; Rogers, 1977).

Table 5. War establishment manpower by British Royal Navy

Period of war	War establishment manpower
War of Austrian succession 1748	44,861
Seven Years' War in 1762	84,797
American war of Independence in 1783	107,446
Napoleonic Wars in 1810	142,098

Source: Williamson (2002)

- *The USA.* Figure 5 shows the trend of higher US investment in military expenditure as percentage of GDP in comparison with other leading countries (e.g. Russia, France, and China). Data confirm that the U.S. have high military and defence expenditures in order to

sustain the economic war potential and global leadership for effective and/or potential international conflicts.

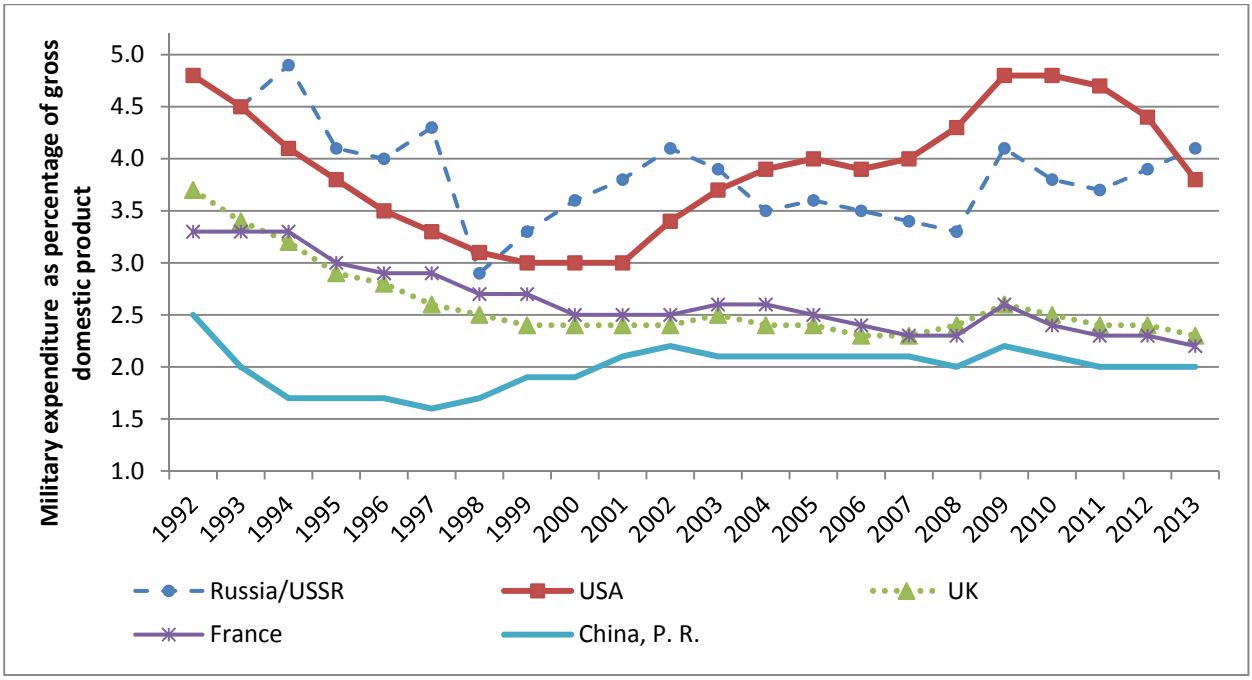

Figure 5. Military expenditures of some leading countries. *Source*: Elaboration on data by SIPRI Military Expenditure Database (2014)

- *High economic and technological performance governed by the global leaders to sustain global leadership over time*.

- *Roman Empire*. It is clearly difficult or impossible to give an exhaustive run down of all ancient technologies originated in Roman history. The measurement and evaluation of commercial technology development in the Roman Empire based on the count of the number of main inventions and innovations does not provide reliable results; however, several historical studies confirm the huge number of discoveries, inventions and innovations by Roman Empire in comparison to other contemporary societies of the Ancient economy (Forbes, 1955-56; Singer *et al.* 1956; Hodges, 1970; Landels, 1978; White, 1984; Greene, 2000; Wilson, 2002). Some innovations are in construction and architectural technology (*e.g.* cement, bridge, aqueducts, etc.), agriculture, surgical instruments, food technology, hydraulic technology, etc. (Greene, 2000). The fruitful technological change by Roman Society was due to high geographical concentration in specific locations of human capital,

technical knowledge, production and dense social networks. The economic activity in the Roman Empire was focused on the generation of state-of-the-art products in military and civil settings for an advanced society in Ancient period (Singer *et al.,* 1956). Moreover, the growth of Roman technological advances was relatively great in the two centuries B.C., in coincidence with some main historical events that sustained the hegemony and global leadership (*cf.* Kelly, 2006; Nicolet, 1991): the period of the Roman Republic (*i.e.* better economic governance); Greece was controlled and Rome had a greater access to new knowledge ; high incentive during the intensive warfare and military victory over Carthage (a rich and potent city of North Africa and belligerent great power for the supremacy of Mediterranean Sea geo-economic area); instead, Roman technological advance was relatively slower from the 1st Century AD onwards due to the beginning of the decline of the Empire and of the global leadership (*cf.* Cipolla, 1970; Ferguson, 2003, 2010). These historical facts seem to show that a global posture to achieve and sustain a global leadership can support and accelerate technological pathways and the generation of groundbreaking commercial products for societies.

- *British Empire*. The acceleration of patents for commercial products in the British Empire, is showed in Figure 6 (Mokyr, 2009; Clark, 2014). In fact, analysis of British patents over 1700-1851 by Bottomley (2007) shows higher technological performances of England, as global leader, in comparison to Scotland and Ireland. This result is due to a powerful English economic system to support the worldwide leadership, whereas Scotland and Ireland did not have any purpose of global hegemony. These fruitful innovative outputs by England during its global leadership are confirmed by Clark (2014).

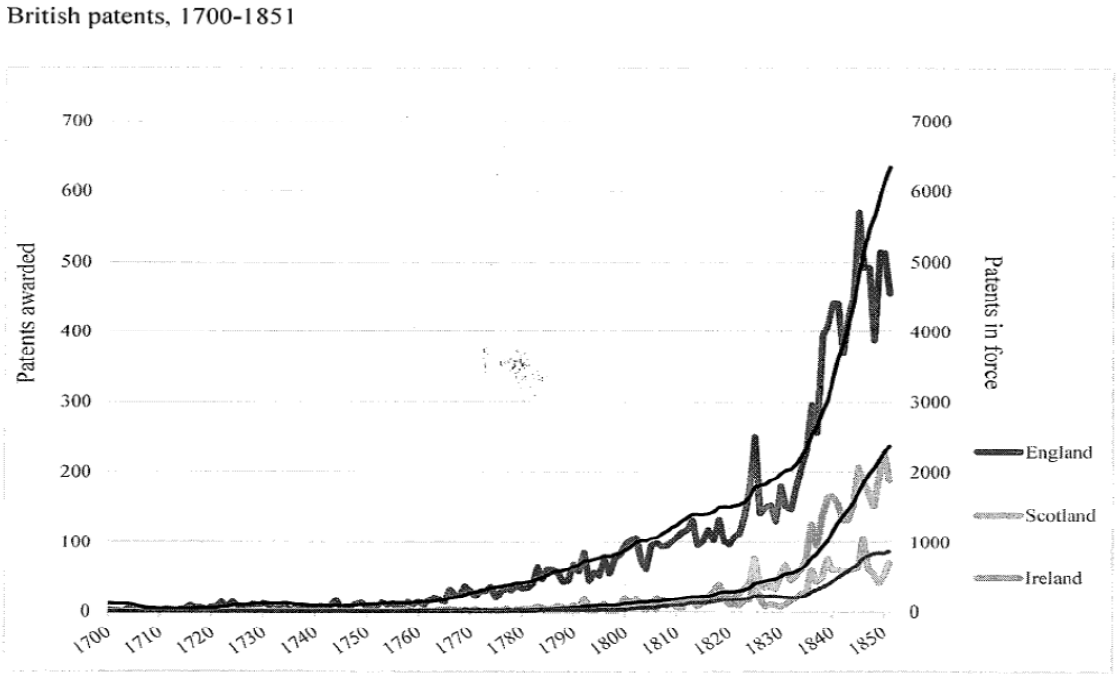

Figure 6. British Patents, 1770-1851. *Source*: Bottomley (2007), p. 15

- *The USA.* Table 6 shows main indicators of US technological development in comparison to other countries. The USA have average military expenditure as percentage of gross domestic product (GDP), R&D intensity, patens applications and GDP per capita higher than other leading countries (Table 6).

Table 6. Technological and economic performances across leading countries

Countries	Average Military expenditure as % of GDP	Average R&D expenditure (% of GDP)	Average Patent applications, residents per million People	Average GDP per capita, PPP (constant 2005 international $)	Average GDP per capita growth (annual %)
	1992-2013*	1996-2005ϕ	1985-2005ϕ	1989-2006ϕ	1990-2006ϕ
United States	**3.90**	**2.66**	**447.20**	**36,318.11**	1.77
Russia	3.87	1.09	145.84	9828.36	0.13
France	2.64	2.18	224.04	27,439.67	1.43
UK	2.60	1.82	334.51	26,565.94	2.03
China P. R.	1.99	0.92	18.00	2,398.01	**8.79**

Note: * SIPRI Military Expenditure Database (2014); ϕ World Bank (2008). In **bold** high performances.

These US higher performances, associated with several socio-economic factors, tend to generate a fruitful technological and economic development worldwide (*cf.* Faberberg *et*

al., 2010; Coccia, 2010, 2014a, 2014b). As a matter of facts, the economic and technological forces of strong performances seem to be associated with the incentive of the USA to sustain the ongoing global leadership.

Considering the model [1] in methodology, table 7 shows the exponential growth rate *r*% of patent applications by U.S. in comparison to High Income OECD countries.

Table 7. Exponential rate of growth of patent applications per million people across geo-economic areas

Exponential rate based on model [1]	**Global leader United States**	**High Income OECD countries**
r %°	44.68	21.62

According to this model, the USA as ongoing global leader tends to have a high growth rate of patent applications (innovative output) in comparison to High Income OECD countries. This acceleration of US economy and technological performances (tab. 6-7) seems to be rooted in the US global posture to sustain the global leadership with a higher technological and economic superiority worldwide.

In short, the results tend to show that countries with global leadership are associated with higher technological performances, driven by main GPTs originated to support this leadership in competitive settings: the inductive study seems to support the hypothesis α of *leadership-driven innovation*.

General Discussion

Global leadership tends to generate high technological performances and, in specific circumstances, revolutionary and disruptive innovations. This result is grounded in the large theory of the incentives to innovate in competitive settings (Bénabou and Tirole, 1996; Calvano, 2007). The global leadership of Rome has generated GPTs in engineering and construction

technology, England as global leader has caused the Industrial Revolution based on steam engine technology, whereas the global leadership by the USA has originated Telecommunications Revolution.

Hence, new techno-economic paradigms tend to be originated by great powers during international conflicts to achieve/sustain the global leadership and diffused in the long-run on wide and stable geo-economic systems. These common characteristics at the origins of GPTs seem to show some historical regularity: the origins of path-breaking technologies in international conflicts and subsequently diffusion are associated with the purpose of achieving/sustaining the global leadership by great powers, rather than warfare *per se.*

Figure 7 shows some main GPTs originated during global leadership of great powers that have generated the evolution of social systems and human development. The duration from the start to the decline of a global leadership (in general a lung-run period) can be defined as a "cycle" that tends to induce changes in the techno-economic paradigm and also likely (*irregular*) K-waves

	Global leadership		
	Roman Empire ➡	British Empire	➡ The USA
Period	*27 BC – 476 AD (Western)*	*~1583-1914*	*~1914-present*
Total duration of the Global Leadership (years)	*~500*	*~330*	*~100*
GPTs	*Construction Revolution by Roads, Aqueducts, Water Mills, etc.*	*Industrial Revolution by Steam Engine (locomotive, steamboat, etc.)*	*Telecommunications Revolution by Computer, Satellites, Internet, ICTs, etc.*

Figure 7. Changes in the techno-economic paradigm and global leadership over time

This inductive study based on historical and empirical analyses seems to validate the HPα (*leadership-driven innovation*) that the origins (and pervasive diffusion) of GPTs and radical technologies are associated with the posture of critical societies to achieve/sustain the global leadership during international conflicts, which generate main processes of social disequilib-

rium. In particular, purposeful country-systems γ tend to generate GPTs mainly in strategic communications and energy systems (and parallel transportation technology) for achieving and sustaining the global leadership. These GPTs are spread in the long run across wide geo-economic areas, generating a social and economic change that supports the evolution of societies. The *pivot* of global leadership within the observed linkages of the sources of new techno-economic paradigms can explain the process that supports the human development.

Ruttan (2006, p. 186) argues a main question:

Will it take a major war or threat of war to induce the mobilisation of the scientific, technical, and financial resources necessary to develop major new general-purpose technologies?

He, considering historical experience, answers: "it may". In fact, according to Ruttan (2001; 2006) a major war, or threat of a major war, may be necessary to induce U.S. political and economic institutions (or some other great powers) to commit the huge resources necessary to generate or sustain the development of new GPTs. But, underlying this correct reasoning, the main driver is *de facto* the posture of US to sustain the global leadership, rather than engaging military conflicts (that are only a means to support the strategic objective of leadership)!

As a matter4 of fact, international conflicts (and global wars in particular) tend to influence positively or negatively some economic processes in a permanent manner. However, this study shows that an international conflicts (and global wars) it is a necessary but not sufficient condition at the origin and diffusion of new techno-economic paradigms. In particular, *the sources of General-Purpose Technologies seem to be purposeful country-systems γ with high economic war potential and the objective of global leadership;*

these purposeful systems γ, to cope with consequential environmental threats of other great powers, tend to generate and implement -by a process of learning and adaptation- several inventions, innovations and GPTs to achieve/sustain the global leadership;

moreover, global leaders spread in the long-run these path-breaking technologies by economic and political mechanisms across wide geo-economic areas.

Hence, the origin and development of GPTs and new techno-economic paradigms seem to be associated with the posture of great powers to achieve/sustain the global leadership by strategic R&D applied to win international conflicts. *International conflicts (military and not / effective or potential) are very strong competitions for the world hegemony and leadership. Main mechanisms of contestable technology are present within these contexts and leading players endeavor to be the firsts in finding a solution of "selected" strategic and technological problems by "selected" technologies for supporting a strategic advantage functional to achieve and sustain a global leadership*[9]. In particular, during international conflicts, a vital goal of purposeful country-systems γ is to support the development of strategic and contestable path-breaking technologies, which can:

a) reinforce the economic war potential;

b) assure strategic advantages in communications and energy systems;

c) sustain the high reputation of great power, increasing the international prestige;

d) ensure credible threats and/or commitment by high technological weapons. As a matter of fact, the technological supremacy generates a main deterrent signalling to discourage some threats of belligerent countries and sustain the incumbent global;

e) generate, in the post war, an economic reward by the commercial technological development of military technology that supports economic growth performances.

Hence, the sources of GPTs can be induced by the posture of great powers to achieve and sustain the global leadership in the presence of international conflicts, when high military interests and overriding needs of solving strategic problems support development of new path-breaking technology. In some specific circumstances, in the presence of a threat and/or a world intensive competition in strategic fields of the "Big Science" (*e.g.* exploration of the

moon and Space), leader countries support radical innovations to reinforce economic war potential, accumulation of capabilities and reputation of global leadership against other Great Powers. At a later stage, mainly in stable economic systems, spillovers for commercial technology development are triggered by global leaders, which spread new technology with a network-oriented approach and trade across wide geo-economic areas.

For instance, radar technology is developed during the World War II by several nations independently and in great secrecy for military objectives and spread for commercial use in the peacetime mainly by global leaders. A main role in this process of development and diffusion of commercial technologies, based on a *"creative" substitution* from old to new technology, is played by public sector. Ruttan (2006; 2006a; 2006b) demonstrates as military and defense-related R&D and procurement (military demand) have supported a radical technological development across a broad spectrum of industries in the U.S. such as in aircraft, computer, semiconductor and space industry (*cf.* Ruttan, 2006; Mowery, 2010). Kira and Mowery (2007) also argue that the development and diffusion of new technology in the USA are due to procurement activity rather than R&D. In fact, initial military demand and procurement are important mechanisms to support emerging technologies by a reduction of technological learning curves (*cf.* Ruttan, 2006; 2006a). Public support for non-military technology development is an important source of radical innovations but successful research programs tend to generate evolutionary rather than revolutionary groundbreaking results such as in molecular biology and biotechnology (Ruttan, 2001; 2006; *see also* Coccia, 2014c, d, e). Some scholars argue that the transition from a military to a commercial jet aircraft likely could be slower in absence of high military R&D performed during World War II and military procurement during the Korean War (*cf.* Ruttan, 2006; Mowery, 2010, p. 1245-1246).

According to Ruttan (2006, p. 177) private sector alone cannot be a source of new general-purpose technologies. *In general, private firms can generate main radical innovations,*

[9] The world "selected" is affected by influential definition of technological paradigm by Dosi (1982, p. 152).

whereas GPTs, which represent the long-run platform for clusters of radical innovations, tend to be generated mainly by countries to achieve/sustain the worldwide global leadership by strategic communications and energy systems (parallel to huge advances in transportation technology, cf. Coccia, 2005).

In short, the international conflict (competition) is *not* the cause of GPTs but the context in which leading countries engender GPTs to cope with environmental threats and to take advantage of important opportunities to achieve the global geo-political leadership.

As a matter of fact, GPTs may not rise without a global leader, with a high military potential, that supports the posture to the global leadership[10].

Ruttan (2006; 2006a;2006b) does not believe that military R&D can again be a source of major new GPTs due to structural change of the US economy and the shift of military objectives towards short-term tactical missions. In addition, the threat of system-level war seems to be ended with the Cold war that has reduced the incentives and overriding needs to invest in major military and defense-related research projects. The observation by Ruttan (2006) is correct *but* is based on a scientific stance of stable economies in peacetime; in the presence of warfare shocks and/or strong turbulence of international crises, the environment and mechanisms of social systems can radically change creating fruitful scientific and technological factors to support the origins of GPTs governed by global leaders and economic change. This is the argument of next section.

Human development and long-run evolution of societies by new techno-economic paradigms governed by global leaderships: a sociological explanation

Wars and global leadership are phenomena of societies that generate sociological problems and main structural changes (social, technological and economic change). A holistic analysis

[10] In order to have a better understanding of this scientific issue, other main studies are by: Acemoglu and Wolitzky (2014), Alic *et al.* (1992), Ayres (1990, 1990a), Berry and Kim (1994), Boot (2006), Coccia M. (2009a, 2010a, 2010b, 2011), Coyne and Mathers (2011), Evangelista (1988), Garden (1989), Ghosh (1943), Goldman and Eliason (2003), Hardie et al. (2011), Horowitz (2010), Jackson and Morelli (2011), Kamen (1968), Kramer *et al.* (2009), Lane (1958), Levy (2011), Libicki *et al.* (2011), Mahnken (2008), Murray and Millett (1996), Natu (1944), Poast (2006), Ransom (2006), Reppy (1998), Rosenzweig (2013), Ruttan (2006), Voigtländer and Voth (2013), Volland (1987), Von Hippel (1988), Walt (1996) and Wolfson (1998).

is important to understand the critical scientific nexus global leadership-sources of GPTs-human development.

The philosophy studies the war to explain its meaning and role for the human development. "War generally impedes [temporarily] economic development and undermines prosperity . . . .War is not without economic benefits, however" (Goldstein, 2003, p. 215; *cf. also* Goldstein, 1988). Although war has several negative effects, it seems to have a main permanent connection with the progress of societies. War appears to be a necessary phase for human development, which is not monotonous and straight but rather a process of disequilibrium (*cf.* Bobbio, 1965). Stein and Russett (1980) argue that the war is the engine that propels economic change and supports the civilisation of societies. It seems that critical technological advances for human civilisation and human development are not originated in peaceful and evolutionary processes. Vital changes in the techno-economic paradigm are caused by processes of disequilibrium governed by global leaders that generate a revolutionary phase of technological and economic change in social systems. In particular, social shocks start with international conflicts but they are the ending of an evolutionary process of social systems that causes a phase of disequilibrium in the state of the system. The long-run effects of these dynamics are social, technological and economic changes that support the evolution of societies and human development (*cf.* Gini, 1920).

In general, international conflicts and competition of "Big Science" for global leadership stimulate the inventive and innovative capability of societies and seem to be, so far, the main condition in which societies create new techno-economic paradigms. In the warfare, when survival of societies is in the running, human mind stretches towards the max concentration and labour to find apt means and priority resources to cope with consequential environmental threats and to achieve the vital objective of the victory (*cf.* von Humboldt, 1961). Under the incentive of the need and in the presence of overriding strategic problems, such as *during a*

war or international conflict, the innovative and creative spirit is intensified. The societies, under concentration and incentive of warfare, endeavor to gain the upper hand and to exploit, particularly, the newest and less known discoveries and inventions of science and technology (*cf.* Gini, 1920). Social and natural sciences and engineering tend to provide in the presence of warfare mainly new contributions based on current and new knowledge to support strategic objectives. In fact, during international conflicts, government interventions in the economic system are necessary in order to have the most effective condition of available human and material resources and obtain the maximum return from socio-economic efforts to cope with belligerent nations. In particular, under concentration of the war, current communications and energy systems improve and new ones are generated to support priority military purposes (Gini, 1920). In general, war is prone to improve all types of communications and parallel transportations that have to generate the max performance because they assume a strategic importance (Mendershausen, 1943).

Some societies with high economic war potential during international conflicts, can take advantage of important opportunities for achieving/sustaining the global leadership. As a matter of fact, global leaders endeavor to support invention and technological innovation of new instruments able to increase their efficiency of available resources and communications (lines). Hence, the critical technological progress of societies seems to be associated with main socio-economic shocks, such as international conflicts, governed by leading countries, which generate disequilibrium processes with long-run effects of social and economic change (*cf.* Spencer, 1904; 1915).

Moreover, socio-economic systems under concentration of warfare, in the presence of overriding strategic problems, tend to overcome resistances and barriers of individuals and/or groups, supporting technological and social advancements to cope with consequential environmental threats; the impetus of this technological and social change is amplified in peace-

time, when economies work with a normal rhythm (*cf.* Gini, 1920). The weaker nations also tend to have vital technological advances, which are difficult to achieve in normal period. The international conflicts spur several societies to be closer to the technological superiority of belligerent countries to cope with threats of turbulent environment. For instance, during Napoleonic wars, in order to increase the food requirement of French population, it was applied the technique of crop rotation (a main agricultural innovation), whereas during World War I and II, the need of economise fuel has supported, in some European countries, the electrification of railway that was a difficult investment in previous pre-war period (Gini, 1920); in the US, the lack of labour during wartime, due to enrolment, has supported the diffusion of agricultural mechanisation with fruitful benefits for American economic system in peacetime.

Global technological and economic landscape of current societies would be vastly different in the absence of military and defense-related investment that tends to induce commercial technology development. In addition, patterns of new technology would have been substantially delayed without the stimulus of international conflicts based on concentration, incentives, military R&D and defense procurement. In fact, needs and strategic problems during warfare are strong incentive for generating new technology of communications, which in peacetime enhances the long-run circulation and cross fertilisation of ideas, supporting social, technological and economic change (*cf.* Bobbio, 1965, *passim*). Several main inventions and path-breaking technological innovations (*e.g.* GPTs) have origins for military purposes governed by leader countries, as described, and in peacetime they tend to be transferred in commercial technology with a pervasive diffusion across geo-economic areas. This process of *leadership-driven innovation* affects social change and patterns of economic growth of winners and losers[11].

[11] Economic literature shows that the economic growth of World War II winners experienced only marginal impact, whereas losers experienced intense losses in the short run, but they were able to regain the positions anticipated by pre-war rates of growth. Organski and Kugler (1980, pp. 106-107) claim this phenomenon as *phoenix factor*: "after their defeat (and the plummeting of their capabilities) loses accelerate their recovery".

During the war a vital characteristic, alike in the biological evolution, is the adaptability of social organisations to stressful conditions by fruitful learning processes. Even the strongest economic war potential does not assure victory if the nation's capacity does not quick adapt to new conditions. In particular, main mechanisms of *learning* and *adaptation* of great powers in turbulent environments are important to support new innovations for copying with consequential environmental threats and/or taking advantages of beneficial opportunities (*cf.* Mendershausen, 1943). Moreover, warfare can determine also a process of social selection: a social survival of the "fittest" social systems in turbulent environment (Stein and Russett, 1980, p. 410). This social selection of the war supports the progress of virtuous and stable organisations (nations). In fact, Great Powers and leader countries, during wars, tend to reinforce their social organisation to progress towards advanced and increasingly efficient socio-economic systems.

A main question is: *why, during peacetime with normal rhythm of the economy or relaxed economic activity, do economic systems not tend to support new techno-economic paradigms?*

A sociological explanation is that the wellbeing of nations during peacetime is prone to induce indolence, inertia, tranquillity and profligate behaviour of people. Nations, in the presence of low environmental threats are without strong incentives and strategic purposes to improve institutions and institutional arrangements. The relaxed national psychology of countries in stable environment tends to weaken *the innovative and creative spirit* and, as a consequence, the incentive to generate and new techno-economic paradigms: in fact, social systems have not any urgent and primary needs to satisfy and strategic problems to solve. Some nations, during peacetime with higher wellbeing, lose several virtues concerning the personality of people, due to the exacerbation of above bad habits that in the long run may reduce the wealth. Virtuous posture of nations that spurs radical innovations and GPTs seems to be originated in the presence of stressful conditions such as in (effective or potential) interna-

tional conflicts. The spirit of privation, the fruitful energy and initiative, the high speed and other talents are the luck of nations during wartime and peacetime. War and environmental threats seem to reinforce the social organisation and strategic behaviour of both stronger and weaker societies. Ruttan (2006, p. 184) argues that without a *threat* of major war, it is difficult that the US political system could be induced to mobilise the priority huge scientific, technical and financial resources to support the development of major military and strategic radical innovations that subsequently can be translated in commercial GPTs for progress of societies (as done in the past). These conditions at the origin of GPTs flourish in the presence of international conflicts and crises, driven by common institutional, entrepreneurial and scientific energies, to cope with consequential environmental threats and to achieve/sustain the global leadership.

This inductive study shows some historical regularities, also underpinned in an empirical evidence, concerning common characteristics driving new techno-economic paradigms in the history of technology. In particular, the determinants for supporting GPTs seem to be (*see* fig. 8):

- A country has a strong economic war potential, based on high R&D investments, and the objective to achieve a global leadership
- It engages (effective or potential) international conflicts (competitions) against great powers (leading players)
- It implements, under concentration and incentive of international conflicts, main radical technologies to solve overriding strategic problems in order to achieve/sustain the global leadership.

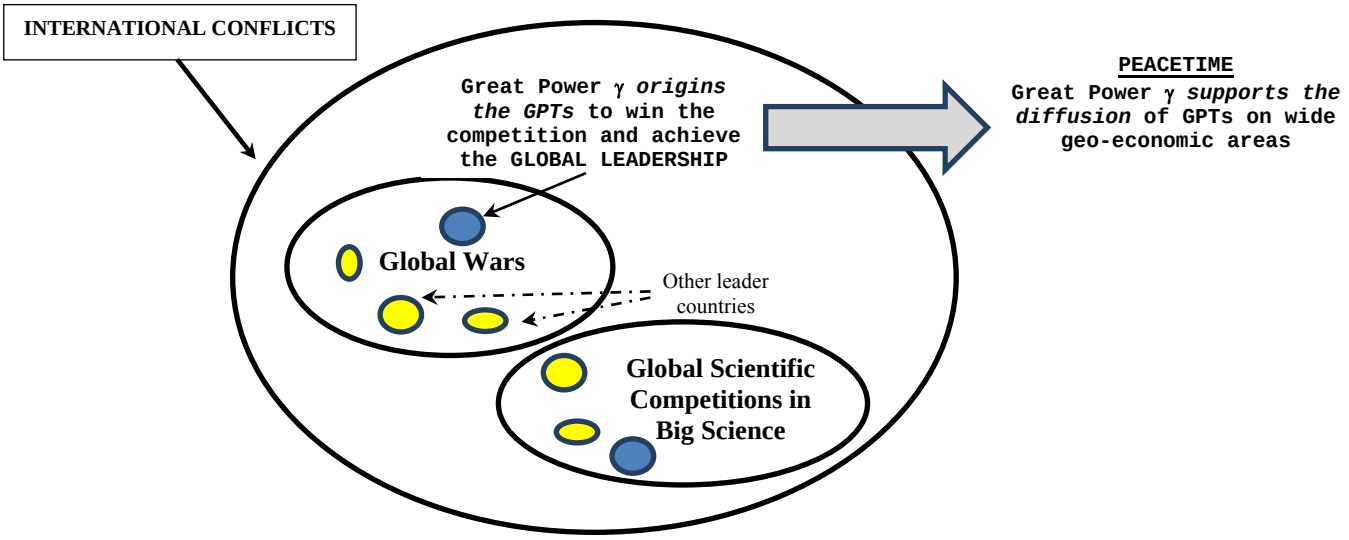

Figure 8. Sources of new techno-economic paradigms by global leader in international conflicts

The war is necessary but not sufficient factor to generate GPTs. In particular, GPTs tend to be originated by the global posture of purposeful systems γ (*e.g.* great power) to achieve/sustain the strategic purpose of global leadership in (effective or potential) international conflicts against leading players. Hence, the other (sufficient) conditions at the origins of GPTs seem to be *the strategic objective of global leadership by a great power that induces the implementation of new technology to win a strong international competition against leading players (competitors), rather than warfare per se.* this main nexus generates the leadership-driven innovation.

In fact, some GPTs are not generated by warfare but by global posture of countries to sustain a global leadership also in extra-military competitions: *e. g.* the strategic competitions/challenges in "Big Science" (de Solla Price, 1963; *cf.* Bush, 1945) and in big technology between US and Russia to explore the Space have also generated some main radical innovations. Hence, although the international conflict (or global war) is the most important competition to achieve/sustain the global leadership and induce GPTs, there are also other intensive extra-military international competitions across leading players to support the global leadership and spur the strong economic, scientific and technological potential of countries.

In short, the sources of GPTs have a main driving factor: a purposeful country γ with the objective of global leadership in a strong international competition across leading players. These global leaders cause GPTs: new technology mainly in communications (such as train, ship, aircraft, satellites, internet, electricity, etc.) and energy systems that are the technical platform for supporting clusters of radical innovations, new technological paradigms and human development (Coccia, 2005). In fact the evolution of some social systems requires new and specialised channels of communications and energy resources.

The global leadership of great powers by these intensive competitions/conflicts can be a driving force of social, technical and economic change that supports the human development and civilisation. In particular, the posture to the global leadership of some countries affects origin, pace, direction and diffusion of vital technological change. The sources of GPTs are generated in social processes of disequilibrium governed by global leader that have economic-wide effects (fig. 8).

In all, human society, although the unparalleled progress of knowledge and technology, it does not know the final destination of his history. The posture to posture to power of some societies can generate new international conflicts and social shocks for achieving the global leadership, causing unforeseeable directions of technological, social and economic change.

Concluding Observations and Theoretical Implications

One should always generalize
Carl Gustav Jacob Jacobi

Global leadership of some societies can provide an adequate and better understanding of social and technological change across economic systems (*see also* Phillips, 2008; 2011). It may be stated that long-term evolution of societies and human development is a process of disequilibrium governed by the dynamics and posture of purposeful country-systems to achieve global leadership in international conflicts that lays the foundations for changes in the techno-economic paradigm. International conflicts, as the main social shocks driven by global lead-

ers, have massive effects on individuals, groups, nations, societies and international systems. They are a major agent of social change (Stein and Russett, 1980, p. 400).

This inductive study supports the hypothesis α (*leadership-driven innovation*) stated in the section methodology that the origins and pervasive diffusion of GPTs can be explained by the posture of leading countries, with high economic potential, which implement a grand strategy of radical innovations to achieve global leadership in the presence of international conflicts (competitions) against main players (great powers). The case study research and statistical analysis – considering the Roman, British and US global leadership – form a body of evidence of historical regularities and common characteristics on the origins of GPTs governed by global leadership.

Linstone (2003, p. 292) shows an interesting scenario:

> You are a forecaster in a superpower that is militarily and commercially dominant in the world. It is technologically superior, has an excellent engineering capability, a sound legal system, and a networked infrastructure to insure effective administration. Its tolerance creates a multicultural melting pot with a growing influx of people from less developed areas. It has a widening gap between rich and poor and a negative balance of trade. Its affluent shun military service and its imperial overstretch requires an enormous military budget. The result is an inevitable dissipation of its resources. No, I am not describing the United States but ancient Rome in the second century.

This inductive study can pinpoint a set of connected and complementary socio-economic results concerning the sources of new techno-economic paradigms:

- *First.* GPTs are associated with the posture of a purposeful country-system with a high economic potential and purposeful elements (*e.g.* coherent set of institutional arrangements) which have the common purpose to achieve and sustain a global geo-economic leadership over time.
- *Second.* The sources of GPTs are underpinned in an environmental context represented by effective or potential international competitions (global warfare and/or worldwide scientific competitions of "Big Science") among great powers seeking to achieve/sustain global leadership.

- *Third*. The strategy of Great Powers to achieve/sustain global leadership during international conflicts in turbulent environments is driven by high military R&D and procurement that spur GPTs.
- *Fourth*. In order to cope with environmental threats in (effective or potential) international conflicts/competitions, global leaders, while attempting to solve overriding strategic problems, generate discoveries, inventions and radical innovations that by a *process of learning and adaptation* are implemented to secure a strategic advantage against belligerent players.
- *Fifth*. Global leaders tend to transfer in a stable environment the *rich* source of military technology into commercial technological innovations for a long-run pervasive diffusion on wide geo-economic areas.
- *Sixth.* GPTs are difficult to nurture without the critical role of a leader society that invests heavily in high military R&D in order to achieve/sustain global leadership.

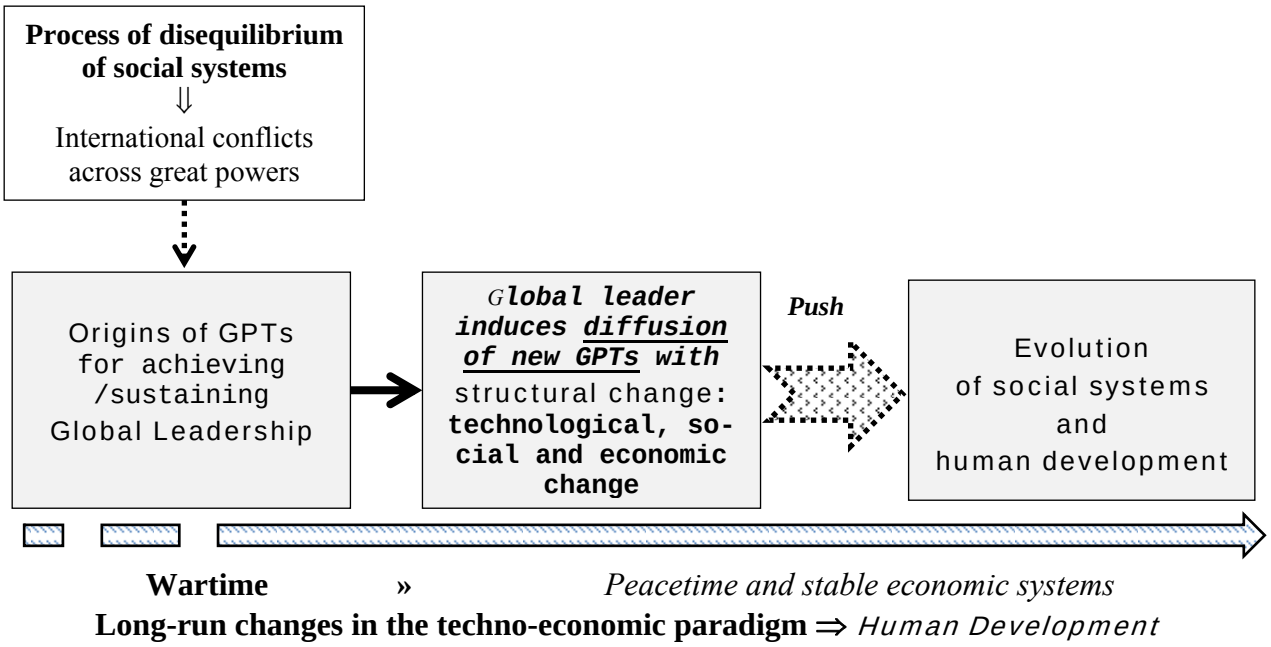

Figure 9. nexus global leadership-origins of GPTs- evolution of social systems

Hence, purposeful systems γ with the aim of global leadership seem to be a major driving force of radical innovations, mainly during effective or potential international conflicts, because "the . . . 'necessity' is the mother of invention" (Ayres, 1998, p. 289, original emphasis). In fact, in the presence of international conflicts, leading countries have environmental stimuli for solving problems in strategic fields that spur technical capability and technological innovations in order to cope with consequential environmental threats and/or to take advantage and exploit beneficial opportunities.

Moreover, the posture to the global leadership of purposeful country-systems γ tends to shape cultural traits of people and institutions to sustain this position in competitive settings over time (*cf.* Spolaore and Wacziarg, 2013). In particular, the posture of global leadership is transmitted within the social system of leading countries across generations over the long run by institutions, which serve as social memory (*cf.* Walker *et al.*, 2006). In fact, the social memory of institutions plays a vital role for transforming experience, knowledge and cultural traits of people into adaptive strategies and learning processes to respond, by technical capability and innovations, to adverse consequences in turbulent environment (*cf.* Di Giano and Racelis, 2012, p. 153). These concomitant characteristics of sustaining global leadership shape *de facto* the posture of leader countries to support continuously fruitful patterns of technological innovation and higher technological performances over time (*cf.* Coccia, 2010, pp. 260-261; Ruttan, 2006; *see* Steil *et al.,* 2002). This theoretical framework can be generalised (*see* Appendix A).

An economic boundary of the global leader can be the high military expenditures to cope with effective (and potential) international conflicts that are prone to increase public debt, socio-economic problems and economic shocks (*cf.* Ferguson, 2003; 2010).

In fact, Kennedy (1987, pp. 539-540) argues:

> To be a great power—by definition, as a state capable of holding its own against any other nation—demands a flourishing economic base. . .Yet by going to war, or by devoting a large share of

> the nation's ''manufacturing power'' to expenditures upon ''unproductive'' armaments, one runs the risk of eroding the national economic base. . . . maintaining at growing cost the military obligations they had assumed in a previous period.

Moreover, vital military technology generated by great powers to achieve global leadership tends, as said, to be spread in peacetime across wide geo-economic areas but may also induce, according to Linstone (2003, p. 288), the: "formation of crazy states or multi-actors. Nuclear, chemical, and biological weapons are only one source of concern".

The global leader with technological supremacy may assume a worldwide role of superpower close to autocracy in order to sustain long-run leadership: this global posture may support a behaviour prone to permanent "wartime" (Linstone, 2007, p. 237). Anyhow, a purposeful country-system γ can spur vital technological change acting as global leaders and *referee* worldwide to avoid discord and war across countries, and to respond in the presence of threats by aggressive and irresponsible states or non-state actors (such as Islamic State of Iraq and Syria (ISIS), Al-Qāʿida, etc., *cf.* Dror, 2001, p.87*ff*). The U.S. tends to assume this role of global leader and *referee, cf.* Linstone, 2007, p. 235). Davis *et al.* (2012, p. 8) argue that: "The United States has an interest in dissuading military competition wherever it might arise. . . . U.S. forward military presence displaying U.S. conventional superiority" (*cf.* Posen, 2003; The White House, 2010; U.S. Department of Defence, 2012). In fact, a purposeful country-system γ with global leadership, underpinned in a technological supremacy and strong economic war potential, can confront: "countries, groups, or individuals with aggressive goals, intense commitment, rational or irrational selection of tools and strategies, preference for high risks, and unconventional tactics" (Linstone, 2007, p. 234; *cf.* Linstone, 2007a; 2003).

In all, the evolution of social systems tends to be driven by global leadership countries that support technological change and breakthroughs (fig. 9). This nexus between technological change and human evolution is a multidimensional and complex socio-economic process because the interrelationships among global leadership, warfare, new techno-economic para-

digms and human development are intertwined with a causality that runs in several directions (*cf.* Goldstein, 2003).

The results of this study have sought to provide a verisimilitude or degree of closeness to true socio-economic facts. In general, the origins of new techno-economic paradigms seem to be associated with strategic behaviour and other concomitant forces of great powers to achieve and sustain global leadership during effective (or potential) international conflicts. Nevertheless, the conclusions of this study are, of course, tentative because current societies are increasingly complex and interconnected systems, and it might prove difficult to identify causes and effects of several relations. In addition, socio-economic analyses, including this study, are problematic when we know that other things are often not equal, such that no results will be true in all situations. Wright (1997, p. 1562) properly claims: "In the world of technological change, bounded rationality is the rule".

Appendix A: Generalisation of the leadership-driven innovation hypothesis

The theoretical implications of this study are that a purposeful system to achieve/sustain the global leadership in competitive settings to cope with consequential environmental threats and/or to take advantage of beneficial opportunities has a strong incentive to support path-breaking innovations inducing long-run structural change (social, technological and economic change). This theoretical framework can explain the drivers, conditions and incentive mechanisms to innovate of several economic subjects in a Schumpeterian world of innovation-based competition. At national level, in the nineteenth century, the purpose of Imperialist policy and global leadership by UK is driven by prevailing theories of mercantilism to create trade monopolies (*e. g.* restricting colonial trade exclusively to British ships and making England the sole market for important colonial products) to support exports, high profits and British wealth.

From macro to microeconomics standpoint, *mutatis mutandis*, the *HP of leadership-driven innovation* can be applied to firms: sources of radical technologies are *purposeful systems* (*e.g.* firms) with high *market potential*, based on a strategy of high R&D expenditures and the *objective of market leadership*. The leading firms, to win *international market competitions* against other great business players, have a strong incentive to generate several discoveries and radical innovations that are spread by market mechanisms across wide geo-economic areas over time. This behaviour of leading firms generates a "destructive creation… destruction rather than creation in driving innovative activity" (Calvano, 2007, *passim*). The posture of firms to achieve and sustain the leadership, investing in R&D, is driven by the prospect of monopoly profits. Moreover, the posture to the leadership of purposeful systems (leading firms) tends to shape specific *routines* that by a process of adaptation and learning are transmitted at organisational level (*organisational learning*) to sustain a *leading* organisational behaviour in competitive markets over time (*cf.* Nelson and Winter, 1982).

Moreover, this theoretical framework can support a fruitful explanation of changes in industry leadership as analysed by Lee and Malerba (2014). Hence, a purposeful firm-system of a country with economic potential to achieve the global market leadership has a strong incentive to implement strategic radical innovations that induce industrial and corporate change.

Figure 1A. Linkages running from leadership to technological, industrial and corporate change

The hypothesis of leadership-driven innovation based on purposeful systems with purposeful elements which have the purpose of leadership induces path-breaking innovations and support long-run structural, industrial and corporate change. It is a conceptual framework that seems to explain several dynamics of current Schumpeterian world of innovation-based competition (Fig. 1A).

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