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A Theory of the General Causes of Long Waves: War, General Purpose Technologies, and Economic Change☆

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ABSTRACT

A debate exists in literature between the Goldstein's theory that Kondratieff-waves (K-waves) or Long Waves (LWs) are linked to hegemonic wars occurring in the final phase of ascending long cycles and studies that do not support this pattern. However, current theoretical frameworks have trouble explaining the sources of LWs with comprehensive and consistent arguments. This study proposes a theory that LWs are due to structural change of warfare that generates huge demand-side effects and powerful supply-side effects to support the evolution of General Purpose Technologies (GPTs) and clusters of innovation. In particular, the analysis here seems to reveal a sequential historical process that runs from wars performed by great powers, occurring in phases of instability of LWs (peak and/or trough), to GPTs and clusters of innovation in the trough of K-waves, which trigger the upward phase of new K-waves. Overall, then, the theory here can be useful for bringing a new perspective to explain, whenever possible one of the general sources of the evolution of LWs, rooted-in-war, that generates technological and economic change in society.

To Harold A. Linstone who started me on this path.[1]

1. Introduction

A continuing debate exists between the Goldstein's theory that Kondratieff-waves (K-waves) or Long Waves (LWs) are linked to hegemonic wars occurring in the final phase of ascending K-waves (Goldstein, 1988) and studies that do not support this pattern (e.g., Reijnders, 2006).

The literature in this research field has investigated several characteristics of LWs, such as technological transformations (Ayres, 1990a, 1990b; Mosekilde and Rasmussen, 1986; Grinin et al., 2017), stability and timing associated with geophysical origin (Berry, 2000), biological determinants (Devezas and Corredine, 2001), economic factors (Sterman, 1985), substitution between primary energy sources (Volland, 1987), leadership generations (Berry and Kim, 1994), possible causes (Modelski, 2001), surprising events ("X-events", Wilenius and Casti, 2015, p. 335*ff*), emerging technologies (Linstone, 2003, 2004, 2006, 2007a, 2007b, 2010; Linstone and Devezas, 2012),[2] technological breakthroughs for next K-Wave (Grinin et al., 2017), etc. However, current theoretical frameworks have trouble explaining the general sources of LWs with comprehensive and consistent arguments. In fact, it is hardly known *how* Long Waves (LWs) emerge and evolve (Ayres, 1990a, 1990b; Devezas et al., 2005; Coccia, 2010a, 2010b, 2010c, 2010d; Linstone, 2004, 2007a; Mensch, 2006; Linstone and Devezas, 2012; cf., Coccia, 2005b, 2007, 2009c, 2016a, 2016b, 2016c, 2016d, 2016e). Especially, "what causes K-waves" it depends also on "What is the why and how of major innovations, and why and when do they bunch?" (Modelski, 2001, p. 78). The problem underlying these scientific questions is to explain the general determinants of Long Waves. This study suggests the hypothesis of rooted-in-war long waves

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[1] *Harold A. Linstone*-Founding Editor and Editor-in-Chief 1969–2010 of Technological Forecasting and Social Change. Phillips (2016, p. 1) says that: "Hal was a nice man, a great friend and mentor to many… was an inspirational person with a brilliant mind". I am grateful to Hal for many suggestions that he has given me during several conferences worldwide and in particular, I will never forget the impetus to study Long Waves. I maintain this main Hal's legacy and I dedicate to him this scientific contribution. Thanks Hal.

[2] Cf. also Ayres (1990a, 1990b), Devezas et al. (2005), Coccia (2010a, 2010b, 2010c, 2010d), Linstone (2004, 2007a, 2007b), Mensch (2006), Linstone and Devezas (2012). *Note*: This study uses the terms Long Waves (LWs), Kondratieff Waves (K-Waves) and Long Cycles interchangeably.

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that one of the sources of Long Waves is the interplay between warfare and emergence of General Purpose Technologies (GPTs) and clusters of innovation. In particular, the study here endeavors to see whether historical, statistical and economic literature investigation supports the hypothesis that specific and distinct wars performed by great powers are associated with GPTs and clusters of basic innovation in the trough of K-waves, which trigger the upward phase of new K-cycles. In order to position this analysis within existing literature, this study begins by reviewing some studies in these research fields and by developing the theoretical framework of this contribution.

2. Theoretical framework and working hypothesis

Several scholars have done many studies in the field of K-waves or LWs (Kondratieff, 1935; Coccia, 2010a; Devezas, 2006). Devezas and Corredine (2001, pp. 414ff; Grinin et al., 2017) analyze the biological determinants of LWs that may be due to "natural human biological clocks" that impose the rhythm of collective behavior by learning processes over time (cf., Modis, 2006). Goldstein (2006) explains the dynamics of LWs with causal relationships among critical factors such as war, production and innovation. In particular, war can generate consequences on investments, prices and real wages of economic systems (Goldstein, 2006). As a matter of fact, wars performed by great powers can be an agent of social change that influences negatively and/or positively in a permanent way some socioeconomic processes of inter-related economies (Stein and Russett, 1980, p. 399). In general, the investigation of war economy and mainly of war consequences can help to explain some principles of economic, social and technical change (cf., Coyne and Mathers, 2011; Marchetti, 2006; Ransom, 2006; Rasler and Thompson, 1985; Poast, 2006; Smith, 1985). There are different typologies of wars, such as interstate armed conflict between two or more states, internal armed conflict between state and group within its territory, minor conflict with 25–999 deaths per year and major conflict with 1000 + deaths per year (Norris, 2009). Major wars are a component of "hegemonic cycles" of nations with global leadership (duration of these cycles is about 150 years since 1500 CE -Current Era-, Goldstein, 2006). The distinctive hegemonic wars between great powers generate long-term structural change, new distribution of international power and other socioeconomic and technological consequences between winner and loser nations (Coccia, 2015; Gini, 1921; Stein and Russett, 1980, p. 401; cf., Rasler and Thompson, 1985). In this context, the Goldstein's theory posits that K-cycles are linked to hegemonic cycles and hegemonic wars always occur in the final phase of ascending K-waves in the presence of a weak hegemony of dominant nations (Goldstein, 1988; Jourdon, 2006, pp. 166–167; Modelski, 2006). In particular, winners of hegemonic wars can dominate in military, economic and financial fields worldwide. Mensch (1979, p. 73) shows the role of American wars in K-waves from 1745, such as the American revolution in the 1st wave, the war of 1812 and Mexican war in the 2nd wave, the Spanish-American war in the 3rd wave, the WWI, WWII and Korean war in the 4th wave (cf., Linstone, 2006, p. 261ff). Reuveny and Thompson (2006) argue that within LWs, economic growth leads to hegemonic war and, in turn, leads to economic growth: this is the leadership long cycle theory of growth-war relation. Instead, Sorokin (2006) claims that a new cycle of technological development can lead to war conflicts and change of powers between established centers. To put it differently, the meeting point of technological cycles (i.e., the termination of one cycle and start of next one) might induce conflicts and subsequent diffusion of a new technological cycle over the long run (Sorokin, 2006, pp. 253–254).

Generally, these studies argue that wars tend to occur at the end of Kondratieff upswing, to intensify the tensions of boom, to destabilize socioeconomic relations and to usher in the ensuing downswing. However, Reijnders (2006, pp. 145ff) claims that World War II does not fit this pattern, because it occurred at the end of the Kondratieff downswing, followed by an upswing. These arguments are consistent with the study by Berry (2006) that K-waves have two types of instability, trough and peak, which can coincide with warfare.

Overall, then, it is clear that there are at least some factors and mechanisms of the evolution of LWs that these studies have trouble explaining with consistent arguments. Hence, it would seem useful to explore and suggest alternative hypotheses for explaining the drivers of long waves.

Firstly, "what causes K-waves" is also associated with "why do K-waves run out of steam, and when do they do that" (Modelski, 2001, p. 77–78). Mensch (1979) showed the linkage between basic innovation clustering and the evolution of K-waves; in particular, Mensch (1979) argues that basic innovations tend to be concentrated in the down slope and bottom of K-waves: the period of "creative destruction" (Devezas et al., 2005, p. 917). The recovery and prosperity phases of K-waves are then triggered through the diffusion of new technology with radical and incremental innovations, their commercial introduction, and widespread adoption of new products/processes in markets (cf., Linstone and Devezas, 2012; Coccia, 2010a; Korotayev et al., 2011; Marchetti, 1980; Calabrese et al., 2005).

Secondly, Modelski (2001, pp. 76–7) also claims that:

> the K-wave is a bunching of basic innovations that give rise to leading industrial or commercial sectors, producing S-shaped surges of growth…. K-waves might therefore be defined as processes of the rise and fall of lead sectors, or for short as structural change in the global economy… the now more widely perceived notion of K-waves as 'gales of creative destruction' paving the way for new technological paradigms…. K-waves are, in the first place, endogenous to the global economy. But, in the second place, they are also interlinked with other subsets of human organization, such as political, social, and cultural, and these must also be explored.

Clusters of basic innovation in the bottom of K-waves can be due to General Purpose Technologies (GPTs): "a technology that initially has much scope for improvement and eventually comes to be widely used, to have many users, and to have many Hicksian and technological complementarities[3]"(Lipsey et al., 1998, p. 43). GPTs generate a "destructive creation" (Calvano, 2006) making prior products obsolete and giving rise to increasing returns-to-scale, such as steam engine, electric motor, and semiconductors (Bresnahan and Trajtenberg, 1995, p. 83; see also Jovanovic and Rousseau, 2005, p. 1185ff; Rosenberg and Trajtenberg, 2004). Characteristics of GPTs are the scope for improvement, wide variety and range of uses during its evolution and strong complementarities with existing or potential new technologies (Lipsey et al., 1998, pp. 38ff). In general, GPTs can support a shift of techno-economic paradigm that accumulates a string of innovation in the trough of K-waves with pervasive effects in the future for almost every branch of the economy (Ayres, 1990a, 1990b; Bresnahan, 2010, pp. 763–791; Helpman, 1998; Lipsey et al., 1998, 2005; Mensch, 1979; Modelski, 2001; cf., Coccia, 2005a, 2005b, 2005c, 2006, 2009a, 2010a). Moreover, the spatial and temporal diffusion of GPTs generates several ripples of effects that permeate economic systems of inter-related nations and induce corporate, industrial, economic and social change (Peirce, 1974, 1975; Rosegger, 1980; Coccia, 2005a, 2005b, 2005c, 2015; Phillips, 2011).[4]

The theoretical framework just mentioned above suggests a relation between warfare, GPTs and evolution of K-waves that can support the

[3] Hicksian complementarity occurs when innovations lower the cost of some good that is used as an input in several production processes (change of some price). Technological complementarity cannot be modelled as changes in the prices. It takes place in the structure of capital and consequent changes will typically take the form of new factors of production, new products and new production functions (cf., also, Cavallo et al., 2014a, 2014b, 2015).

[4] Cf. Coccia (2005a, 2005b, 2005c, 2009a, 2009b, 2010a, 2010b, 2010c, 2010d, 2010e, 2011, 2012a, 2012b, 2014a, 2014b, 2017; Coccia and Finardi, 2013; Coccia and Rolfo, 2000; Coccia and Wang, 2015, 2016).