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Possible technological determinants and primary energy resources of future long waves

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ABSTRACT: The purpose of this paper is to conjecture the possible underlying technological determinants of future long waves, based on prominent studies of scholars and leading forecasting companies; in particular, this research assumes the converging of nano-bio-info-cogno technologies to be the foundation of 5th and 6th economic cycles, whereas the future technological revolution that may underpin the 7th long wave is assumed to be Faster-Than-Light technologies. The positive effects of these future technological revolutions on worldwide economic system are a high increase of productivity, employment rate, consumption and economic growth that lead to longer, happier, and healthier living as well as general well-being.

KEYWORDS: Long Waves**,** Technological Revolution, Forecasting, Foresight

JEL-CODES: E30, E37, O33

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1. INTRODUCTION

The current debate over long waves or Kondratieff waves (in short K-waves) theory has been ongoing since the first substantial evidence in 1920s (Kondratieff, 1926, 1935; Volland, 1987; Ayres, 1990 and 1990a; Berry *et al.*, 1993; Devezas *et al*., 2005). Kondratieff's contribution on the causes of long waves was weak. Schumpeter (1939) argues that technological revolutions and their diffusion forces drive the long cycle. Scholars also point out other primary causes of long waves, such as capital accumulation, war/hegemony, Marx dialectics, institutional changes, and so on (Papenhausen, 2008), therefore, there is a vast economic literature that considers Changes of Techno Economic Paradigm (Technological Revolutions) the main foundation of long wave paths (Ayres, 1990; 1990a; Kleinknecht, 1990; Reati and Toporowski, 2004; de Groot and Franses, 2008; 2009). According to Freeman and Soete (1987), *these are far-reaching and pervasive changes in technology, affecting many (or even all) branches of the economy, as well as giving rise to entirely new sector. Examples given by Schumpeter were the steam engine and electric power*.

This innovation produces the highest impact on the geo-economic system (Coccia, 2005): *The means of human communication are radically changed and a new means of communication, which heavily affects all the economic subjects and objects, originates, forcing all people/institutions to change their habits.* This technological revolution - structural change - occurs by clusters of radical and incremental innovations over time that modernise the whole productive structure and underpin each long wave path (Freeman and Louçã, 2001). For instance, the technoeconomic paradigm based on steam engines is the driving force of the first Kondratieff wave (Mokyr, 2002), as well as the Information and Communication Technologies are the foundations of the 4th long waves (Devezas *et al*., 2005). These technological revolutions are pushed and powered by (new) energy resources, which support the economic cycle of long waves in the world market (Marchetti, 1979; 1988).

The purpose of this essay is to conjecture the possible driving technological forces, as well as primary energy resources that would underpin fifth, sixth, seventh long waves, considering some studies of prominent scholars and leading foresight companies.

2. DRIVING FORCES OF LONG WAVES ON FORECAST HORIZON

Devezas and Corredine (2001) have showed that the long wave behaviour has biological determinants. Other prominent papers have focused different causes of long waves (see Modelski, 2001; Papenhausen, 2008), however I focus the technological revolution as vital cause of long wave cycle.

In primis, Coccia (2009) assumes the forecast horizon (periods between today and the date of forecast) of 5-6-7 K-waves based on arithmetic mean of previous chronologies worked out by Kondratieff (1935), Ayres (1990, 1990a), Mandel (1980), Mensch (1979), Kuznets (1965), Van Duijn (1983), Berry (1991; 2000), Devezas *et al.* (2005). Table 1 shows this forecast horizon of long waves based on US and UK data.

TABLE 1: FORECAST HORIZON FOR 5^{TH} – 6^{TH} – 7^{TH} LONG WAVES BASED ON AVERAGE TIMING OF US AND UK DATA

Waves	*Timing of beginning (arithmetic mean) year* [a.]	*Timing of the boom (arithmetic mean) year* [a.]	*Timing of end (arithmetic mean) year* [a.]	*Period (arithmetic mean) year* [a.]	*Forecast error Deviation Standard year*
1-K	1779.50	1811.25	1837.50	58.92	-
2-K	1837.67	1866.67	1891.83	54.17	-
3-K	1892.00	1918.83	1944.50	52.67	-
4-K	1944.50	1973.50	1992.00	54.00	-
5-K*	**1992.00**	**2021.15^**	**2046.94**	**54.94**	**2.37**
6-K*	**2046.95**	**2076.09^**	**2101.88**	**54.94**	**2.37**
7-K*	**2101.89**	**2131.03^**	**2156.82**	**54.94**	**2.37**

Note:

***** value estimated by arithmetic mean of previous K-waves

a. these years are average timing based on chronologies of long waves elaborated by Kondratieff, Ayres, Mandel, Mensch, Kuznets, Van Duijn, Berry, Devezas *et al*.

Source: Coccia (2009)

Linstone (2004) claims that the fifth K-wave will be based on a molecular era. In particular, this long wave as well as part of sixth one could be underpinned by converging of nanotechnology, biotechnology, information technology and cognitive technological innovations (Bainbridge and Roco, 2006). In fact, the high potential impact of these converging technologies can have main social implications for improving wealth and well-being of future generations.

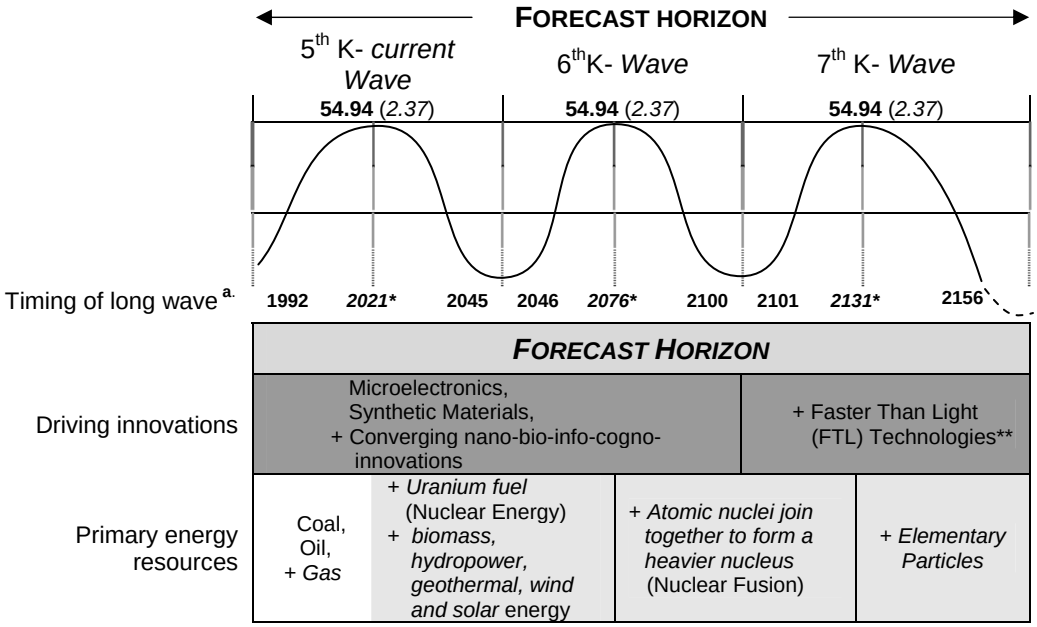
Instead, to conjecture the technoeconomic revolution that may underpin future seventh long wave (roughly 2100-2166 period), I consider the foresight of BTExtract technologies[1] that suppose the innovation in 2100 or thereabouts of the Faster-Than-Light (FTL) technologies[2].

Whereas, the underlying primary energy resources over this forecast horizon (presents to roughly 2166), should be, for fifth K-cycle, mainly gas and nuclear energy (Marchetti, 1979; 1988) as well as renewable energy such as biomass, hydropower, geothermal, wind and solar energy; nuclear fusion since 6^{th} long wave, and since 7^{th} long wave applications of advances in physics of elementary particles are possible candidates to become primary energy resources.

Figure 1 shows main technological innovations and primary energy resources of future K-cycles over the forecast horizon.

[1] BTExact Technologies is British Telecommunications (BT)'s advanced research and technology business. BT is a large company operating in over 170 countries; BT is one of the world's leading providers of communications solutions and services. Principal activities include networked IT services, local, national and international telecommunications services, and higher-value broadband and internet products and services. BT Futurologists take a look at the potential development of new technologies and virtual worlds, so that products and services can be better targeted to the needs of the customers.

[2] Faster-Than-Light (also superluminal or FTL) communications refer to the propagation of information/ matter faster than the speed of light. FTL, in which matter exceeds the speed of light in its own local region, is *now* considered to be impossible by the physics community because of the special theory of relativity, which prohibits a particle with subluminal velocity to accelerate to, or exceed, the speed of light in a vacuum (special relativity does not forbid the existence of particles that travel faster than light at all times). On the other hand, what some physicists refer to "effective" FTL is the hypothesis that unusually distorted regions of space-time might permit matter to reach distant locations faster than light what it would take light in the "normal" route (though not faster than light moving through the distorted region). Effective FTL is not excluded by general relativity. Examples of effective FTL proposals are the Alcubierre drive and the traversable wormhole, although the physical plausibility of these solutions is uncertain (Feinberg, 1967; Gonzalez-Diaz, 2000).



Note:
All numbers are years and their factions. In **Bold** there is the average timing and period of 5th -6th -7th K-Waves estimated considering previous chronologies; (*in parenthesis*) there is the Deviation Standard, that indicates the forecast error of K-waves over forecast horizon

* It is the average timing of boom

** BTExtract Technologies Foresight

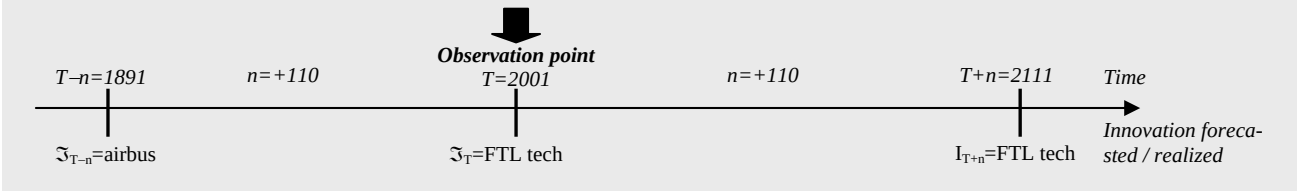
\+ Symbol indicates additive elements to innovations/energy resources originated in previous K-waves

a. Average timing of long waves based on arithmetic mean of chronologies worked out by Kondratieff, Ayres, Mandel, Mensch, Kuznets, Van Duijn, Berry, Devezas *et al.*

FIGURE 1: FORECAST HORIZON OF LONG WAVES, THEIR DRIVING INNOVATIONS AND PRIMARY ENERGY RESOURCES

As we are not able to prove by empirical evidence that foresight of FTL technologies in 2001 by BTExtract technologies will be realized in 2111, when it would start 7th long wave path, I conjecture a logic proof.

In primis, I present the following vital diagram:



The notation $\mathfrak{I}$ indicates the innovation forecasted, whereas **I** indicates the innovation realized in the market place. ***T*** indicates the time period; ***n*** = forecast horizon.

Hypotheses

- $\mathfrak{I}_{T-n}$= innovation forecasted in T–n and it is a successful innovation in the marketplace at time T (I_T), such that T–(T–n)=n=forecast horizon; e.g. $\mathfrak{I}_{T-n}$=airbus.
- $\mathfrak{I}_{T-n+1}$= innovation forecasted in T–n+1 and it is a successful innovation in the marketplace at T+1 (I_{T+1}), such that [(T+1)–(T–n+1)] = n; e.g. $\mathfrak{I}_{T-n+1}$ = Information and communication technologies (ICTs).
- $\mathfrak{I}_T$ = innovation forecasted in *T*= FTL Technologies.

Proposition

Let *T* = 2001 year of foresight; *n* = forecast horizon = 110 years;

If innovation forecasted in *T–n, i.e.* $\mathfrak{I}_{T-n}$ is realized in *T* (I_T) $\Rightarrow \mathfrak{I}_T$ is realized in T+n (*i.e.* I_{T+n})

Proof.

If I_{T+n} forecasted in $\mathfrak{I}_T$ is a contradiction,

than

I_{T+n-1} forecasted in $\mathfrak{I}_{T-1}$ is a contradiction,

I_{T+n-2} forecasted in $\mathfrak{I}_{T-2}$ is a contradiction,

by backward induction, it is possible to state that

I_{T+1} forecasted in $\mathfrak{I}_{T-n+1}$ is a contradiction,

I_T forecasted in $\mathfrak{I}_{T-n}$ is a contradiction,

nevertheless, the last statement is true per hypothesis [*reductio ad absurdum*] and the statement $\mathfrak{I}_{T-n+1}$ also is true per hypothesis, hence per forward induction,

I_{T+n} forecasted in T, *i.e.* $\mathfrak{I}_T$, is true, Q.E.D. □

3. CONCLUDING REMARKS

In short, the clusters of FTL innovations in foreseeable future can generate new techno-economic paradigms that will underpin future 7th long wave and economic growth patterns. The revolutionary applications of these developments will positively impact on improving human condition. In particular, this type of innovative development leads to new range of products, services, systems, and industries in the sector directly involved as well as affects, directly or indirectly, almost every other sector of economic system. The means of human communication will be radically changed by new technologies of communication. In addition, future revolutionary innovations (with the highest impact on socio-economic system) permit higher mobility of people, goods, capital, and information, and lower time to travel and communicate will be considerably (Coccia, 2005). In other words, if $\tau(t)$ is the function period spent to travel and communicate (time is the explanatory variable), with revolutionary innovations, such as FTL Technologies,

$$\lim_{t\to\infty} \tau(t) = 0$$

The positive effects of future technological revolutions on worldwide economic system are a high increase of productivity, employment rate, consumption and economic growth that lead to longer, happier, and healthier living as well as general well-being. In brief, future revolutionary technologies will ever improve our lives in many ways.

In conclusion, we must not forget that the future is hard to predict but one thing is certain, the high potential of future revolutionary innovations over forecast horizon are now in the scientific incubator of mankind, and we have to be aware that they will appear and spread in not-too-distant future, although we are not able to see and benefit, some of them, in our lifetime.

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