Statistical analysis of Kondratiev water long

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Abstract. This article analyzes the dynamics of main macroeconomic indicators of economic development in order to reveal wave motions, determine decline and growth periods in economy as well as show the reasons of cyclicality in economic development. Basing on N.D. Kondratiev's theory, this article analyzes the dynamics of economical development in the USA over a period from 1775 to 2010. The resulting conclusion confirms existence of structural cycles in economy caused by the governmental monetary policy.
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Introduction

Kondratiev's theory of long waves attracted significant attention in various disciplines, including researches of long-term economic growth [1]. Many researchers believe that conclusions and results of Kondratiev's observations were biased as the very idea of long waves in economy was advanced without solemn theoretical justifications. Kondratiev's empirical analysis included only some indices of economic development. Kondratiev himself admitted that manufacturing and consumption indices he had chosen as initial data couldn't reveal the cycles with adequate accuracy. He also admitted that his manipulations with selected data were defective as all elements of the capitalist economy are interrelated [2].

Long waves describe the process of long-term economic growth and are supposed to justify the most important changes in the capitalist mode of production [3]. In his theory, Kondratiev shows approximate timing of long waves of economic development [4]. These were the first attempts of quantitative research of economic history. According to the theory of Kondratiev and several other scientists, the industrial growth started to accelerate rapidly around 1780, mainly due to the increase in iron production [2], [3]. This growth was interpreted as the expansion phase of the first long wave, or "The Industrial Revolution" in England in the period from 1780 to 1840. Later on, four more long waves were revealed starting from the times of the first industrial revolution. The second wave was caused by the steam engine and railroad construction, the third wave, as it is known, by electricity, telephone, radio and heavy engineering. The fourth wave was based on automobile and mass production. The fifth current wave is based on information resources and telecommunications. Some authors add biotechnologies to the fifth wave [5]. As C.Perez says, every wave has its attributable core, rationales of companies, new transport infrastructure and corresponding organizational changes [6].

Many economists deny existence of Kondratiev's waves as there are too many departures from his rules. Kondratiev put forward his theory in mid-twenties of the 20-th century, and although his work was published in German and English, it didn't attract ample attention. However, the situation changed on Black Tuesday of 1929, when economists failing to explain the sudden economic crisis decided to turn to Kondratiev's works. But trying to implement his theory for analysis of economic development dynamics, scientists revealed significant inaccuracies which caused fierce criticism of the theory.

According to Kondratiev's statement, «…It's possible to think that the material basis of big cycles is deterioration, change and expansion of main capital goods which require protracted periods of time and vast investments to be produced. Changes and expansions of this goods stock occur unsmoothly, spasmodically, as represented by big waves of economic activity» [7].

Analyzing the casual mechanisms of long waves, Schumpeter says about the decisive role of technological and organizational changes as essential features of a long wave. Schumpeter's theory is focused on innovations which represent the economic growth engine. He claims that "the process of creative destruction is an essential fact of capitalism", [8] and the process of decline of old technologies leads to cyclicality of economy [9]. Thus, economy develops basing on accumulation of innovations. Besides, Schumpeter claims that innovations are historical by their nature and could only be understood within the innovation clusters which change not only the production structure, but organizational and institutional structures as well [3].

Kondratiev emphasizes that "the period of economic recession of long waves is characterized by a large number of important discoveries and inventions in technology and production which, however, are usually used on a large scale at the beginning of the next long expansion" [2]. This idea was used by Schumpeter and served as a basis for his theory of "innovation clusters" [10]. Under this approach, each Kondratiev's wave is connected to a certain core industry or manufacturing process [11]. This assumption has been elaborated in works of many economists [12], [13], [14], [15], [16], [17], [18], [19], [20].

Theory and methodology

Kondratiev's theory was subjected to severe criticism by Kuznets [21]. And not earlier than in 1980-s Mensch managed to empirically justify the 50-years cycle of implementation of large innovations on markets [22]. Proponents of long waves in economy supplemented a significant amount of additional empirical data supporting Kondratiev-Schumpeter theory [23], [24]. In 2003, opponents of the long waves theory used Poisson regression to prove that there were no innovation clusters [25].

C. Freeman described the following causes of long waves: emergence and expansion of a cluster of radical innovations which have a great potential for extra profit and are based on technological superiority as compared to previous production modes [3].

In his monograph «Technological Revolutions and Financial Capital», C.Perez described the process of wave dynamics with the use of innovations [6]. Although in many researches innovations are put forward as a cause of long waves, there's no consensus among the scientists as to the mechanisms causing long-wave motions. For instance, many famous theories of long waves focus on capital investments and Marxian [26], [17]. Long waves were connected to inflation shocks and large wars [27]. It is necessary to note that in recent decades such explanations of long waves haven't been used. At the present time, price indices are used for analysis of waves in economy [28]. Kondratiev revealed wave dynamics on the basis of dynamics of capital investment. This approach was further developed in works of Forrester and his colleagues [29], [30], [31]. However, in recent decades the most popular explanation of the long-wave dynamics has been the dynamics of technological innovation development.

Price levels, inflation, gold price, GDP and stock indices have been chosen for the analysis of long waves in this article. Changes in measures speak for certain inaccuracies in phases of long waves as described by Kondratiev. «From the abstract point of view, national and world economy constitutes continuous dynamic process of interrelationships and connections of the element system» [2]. This statement once again proves that the studies of economic development dynamics, determining of recession and growth periods must be based upon the analysis of macroeconomic measures.

Kondratiev's long waves are divided into four phases: depression, expansion, recession, plateau (winter, spring, summer, autumn). Transitions between the cycle phases are connected to technical progress which influences the production level. A steam engine which was an incentive for the great industrial revolution may serve as an example of such technology.

Kondratiev determined three phases of long waves, the fourth and fifth waves were determined by his followers (Table 1) [32], [33], [34], [35], [36], [37], [38], [39], [40]).

Table 1. Timing of K-waves

Wave number	Cycle phase	Start date	End date
First	expansion	1780-1790	1810-1817
	downturn	1810-1817	1844–1851
Second	expansion	1844–1851	1870–1875
	downturn	1870–1875	1890–1896
Third	expansion	1890–1896	1914–1920 (1928-1929)
	downturn	1914–1920	1939–1950
Fourth	expansion	1939–1950	1968–1977
	downturn	1968–1974	1991–2001
Fifth	expansion	1991–2001	?
	downturn	?	?

Five Kondratiev's waves describe the situation since the time of the first industrial revolution and up to the present moment. Interestingly enough, Kondratiev emphasized the connection between the economic and political cycles. He noticed that wars started in early phase of economic growth (the turning point between spring and summer), while peaceful time aligns with the phase of economic stagnation, and revolutions are common during the transition between the stagnation phase and rapid growth [2]. Four suchlike cycles have been described since the time of the industrial revolution.

Statistical analysis Kondratiev's long waves

Analysis of statistical data provides evidence for existence of certain inaccuracies in explanation of long wave phases. It is possible to agree that the thirties were undoubtedly the period of the world crisis, or "Kondratiev Winter", but 1921-1929 was the period of the most rapid economic growth in the US history. 1896-1914 is the growth period according to Kondratiev, and indeed the prices were rising (with the average inflation over this period of 2.5%), but it can be explained by discoveries of major gold deposits in South Africa and Alaska (Diagram 2). The period of 1914-1918 experienced galloping inflation but its reason was an increase in money supply due to the necessity to finance the military activities (Diagram 1). And here's the main question of Kondratiev's theory: is the long waves theory structure formed by a random cyclicality of wars and revolution or the reasons are rooted in structural economic downturns and expansions? [41].

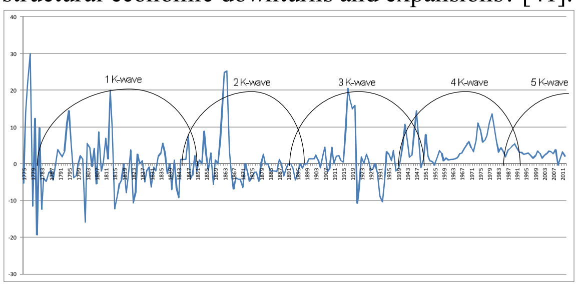


Diagram 1. Dynamics of inflation in the USA, 1775-2012 [42].

But back to the analysis of the first and second cycles. This is a hard task as there was no accurate statistics in the 19th century. According to Kondratiev, the interval from 1835 to 1849 was the period of crisis. The point is, how did the crisis manifest itself? Except for short-term deflation obviously caused by rapid production growth, there doesn't seem to be any reason to believe it was the crisis period.

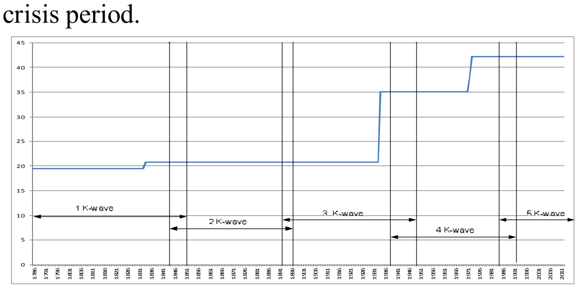


Diagram 2. Official gold price in the USA, 1786-2010 [42].

Analysis of gold prices shows that the prices increased over the indicated period. The economy growth is confirmed by the GDP increase and the price peak is directly connected to the Civil War in the USA (1861-1865) (Diagram 1). "Winter" started in 1873 and lasted till 1896, and again the only crisis indicator was the deflation caused by a major production boom. The boom was triggered by construction of the Pacific railroad (1863-1869) which made a connection between the east and the west of the US. Meanwhile, the US became the world leader in applied technologies. From 1860 to 1890, there were 500 000 patents for new inventions, just as much as in previous 70 years.

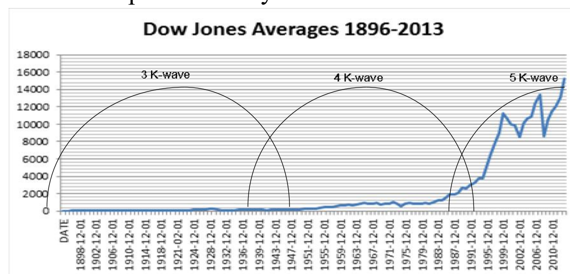


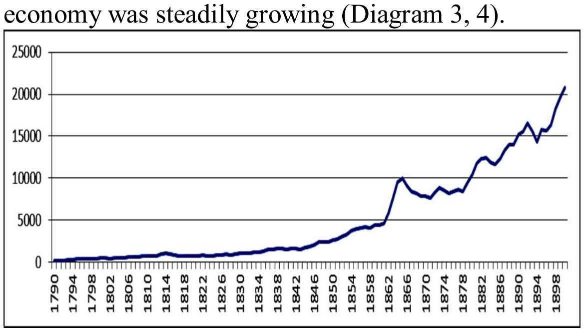
Diagram 3. Dow Jones Averages, 1896-2012 [43].

Stable growth lasted until 1914, the war fostered inflation but the price index stabilized by 1918 [21]. More detailed analysis shows that in 1921the price index fell down, return on bonds fell down, but stocks prices which up to that moment had been following the price index and return on bonds, actually rose although gold prices decreased (Diagram 3). The period of 1921-1919 is usually called the time of the most rapid growth in history of the US. But was it really a growth or just its illusion? Economists still argue about the causes of Black Thursday. The most popular explanation is J. Keynes's theory which says what modern economy cannot stably exist without governmental interference and that capitalism caused the economic crisis [21]. According to Ludwig von Mises, the Great Depression was caused by sharp decrease in interest rates which resulted in dollar supply increase from 45 bln to 73 bln [22]. Such increase in money supply usually leads to galloping inflation but that wasn't the case as the industrial growth "weighted" the prices down. In other words, the government drastically increased the amount of money on the market by providing huge credits and inflated economy which burst on 24th October 1929, triggering the crisis (quite the same happened in 2008 when Americans failed to pay back credits they had taken in times of prosperity). Therefore, not an invisible cyclic market mechanism but irresponsible governmental monetary policy was the cause of a disaster in economy.

The world crisis on the cusp of the 20-s and 30-s of the 20th century initiated political radicalization of European population. World War II started in 1939, and that's the point where Kondratiev's theory is absolutely inconsistent with reality. First, Kondratiev's theory of long waves holds that wars start in the early phase of cyclic economic growth (between spring and summer), but 1939 in

Kondratiev's theory was the year of mid-winter. Second, the depression phase is characterized by decrease in price index, stock price and increase in national debt, but analyzing the US economic measures over that period it is obvious that the price index was growing steadily together with stock prices and the US were quick to pay debts of 1929 (Diagram 3). When the US entered the war, the economy declined, but it was a short period which cannot be called a crisis.

The deep recession of 1973-1975 caused by the oil crisis could count as the beginning of an early winter. However, the beginning of winter means deflation while actually inflation was continuously growing over the indicated period (Diagram 1). Kondratiev's proponents came to the conclusion that the recession of 1973-1975 was a decline at the beginning of autumn, economy was in its resting phase which had to be soon replaced by the next, much more serious crisis. But 10, 15, 20 years passed without any sign of crisis; quite on the contrary, economy was steadily growing (Diagram 3, 4).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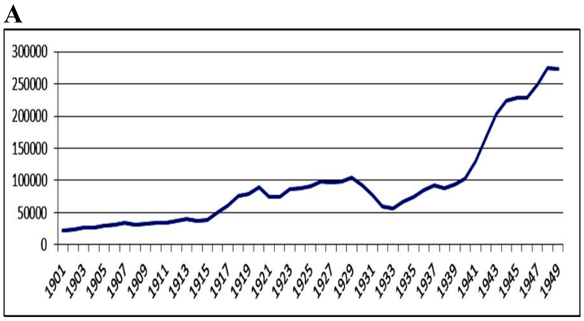
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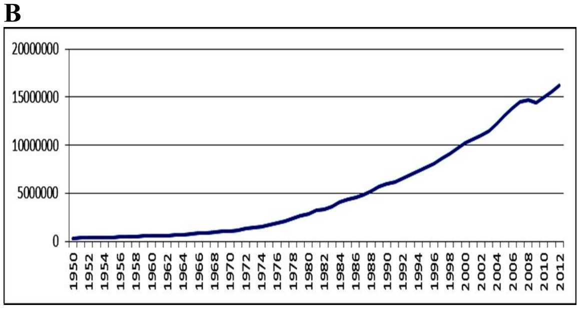
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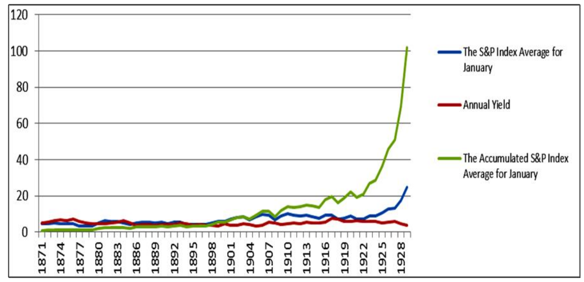
Diagram 3. Gross domestic product of the USA in 1790-2012 (mln $) [42]



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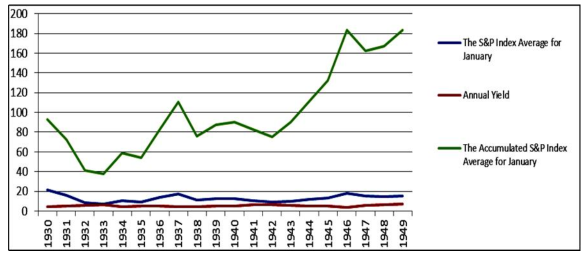

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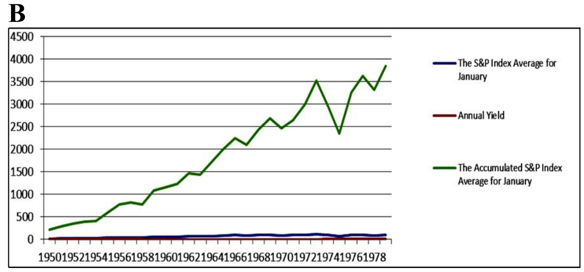

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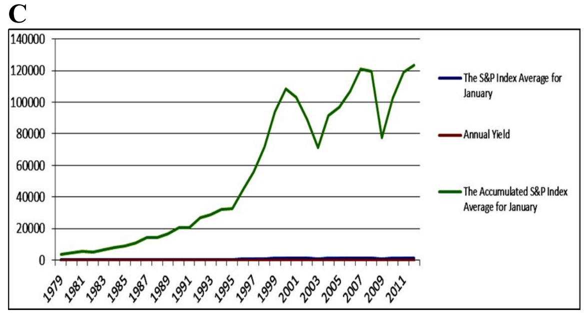

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Diagram 2. Dynamics of stock indices, 1871-2011. [42]

Analysis of price indices, gold prices, inflation and GDP witness significant difference between the long waves theory and actual dynamics of economic development. The first depression predicted by Kondratiev was the period from 1814 to 1849. However, the USA experienced unprecedented bloom and economic growth during this time. The second anticipated depression was expected in 1866-1896. However, in reality it was again the period of economic growth and industrial progress.

Conclusions

If we say that rise in prices is indicative of long waves, it will seem that the price boom lasts just several years, not decades. Throughout the 20th centuries prices have been actually growing during Kondratiev's growth phases. But upon studying all data intensely, other wave phases look clearly distorted. The only real coincidence is the period of 1812-1814 when prices rose due to the war, it can be explained by an increase in money supply in order to cover military expenses. The next price boom in the USA occurred between 1849 and 1861 which is also connected to the civil war. The governmental financing of military expenses inflated and triggered increase in prices and inflation.

As the result, the first two depression phases of Kondratiev's waves prove unfounded. The theory is based on an erroneous assumption that decrease in prices means depression. Prices, as a rule, fall in capitalist society and inflation booms are connected with military spending increases. The third phase of growth indeed lasted from 1895 to 1920. Inflation was steadily growing, but it is necessary to mention that prices were rising due to discovery of new gold deposits in Alaska and South Africa, while increase in prices in 1914-1918 was also caused by military activities. Represented data proves that there's no practical reason to believe that Kondratiev's cycles exist. The cause of economic expansions and downturns is warfare and associated state spending. The observed dynamics shows usual structural cycles in economy which heavily depend upon military actions and consequent inflation.

Following Keynes's theory, one may say that the governmental monetary policy is the cause of cyclic dynamics in economy. State intervention in economy by means of increasing or decreasing of money supply or amount of provided credits creates wavelike processes in economy which are at variance with timing of Kondratiev's cycles. Governmental actions lead to rise in inflation distorting real signals on stock markets. This, in its turn, triggers distortions in production and prices which are later corrected by recessions or depressions [44].

Summing it up, inflation measures cannot be associated with depression or growth phases, their values are more likely to arise from the technical progress and economic decisions of different states. This might be an accident or some real historical conformity that shaped alternating periods of peace and competitive prices and wars with subsequent inflation: the Napoleonic Wars, the American Civil War and the First World War were divided by the interval of 50-60 years, but other global conflicts and crises are open to question. Kondratiev's theory doesn't take into account the Second World War, the Cuban Crisis, the Oil Crisis in the 1970s and many other crises and conflicts.

Inference

On the other hand, one can hardly speak about Kondratiev's theory that was created in market economy, while at the present moment the US, Europe and Russia all have a mixed type economy with significant and, according to Wagner's law, ever-increasing government intervention [45], [46]. The period before the Second World War can be still discussed within the scope of the theory, with arguments pro et contra, but after 1949 it loses all significance. After the downfall of gold standard, too much depends on behavior of national banks and fiscal policy, making it impossible to study economy through the prism of purely market conduct.

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