

Applying Kondratiev Wave Theory to the U.S. Economy: A Historical Analysis and Prospective Future Study of Innovation Cycles and Economic Transformation

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DOI: <https://doi.org/10.64440/BIRUNI/BIR0024>

ARTICLE INFO

Article history

Received Jan 17, 2026

Revised Jan 23, 2026

Accepted Apr 15, 2026

Keywords

Kondratiev Waves;
Long-term Economic Cycles;
U.S. Economy;
Technological Innovation;
Economic Growth;
Economic Time Series;
Digital Economy;
Technological
Transformations.;

ABSTRACT

The hypothesis that the capitalist economy does not develop in a stable, linear manner but rather undergoes long economic waves typically extending between forty and sixty years, during which phases of economic expansion alternate with periods of recession and slowdown.

The study relies on a methodology that combines descriptive analysis and econometric analysis of long-term time series of the U.S. economy during the period from 1800 to 2025, focusing on Gross Domestic Product (GDP) data and a set of complementary economic and social indicators such as unemployment, inflation, international trade, and income inequality. The study also employs a range of modern econometric tools for analyzing economic cycles, such as Spectral Analysis, Fourier Analysis, and Wavelet Analysis, to detect long-term cyclical patterns in economic data.

The results of the study indicate the presence of long cyclical patterns in the evolution of the U.S. economy that largely correspond to the fundamental hypotheses of Kondratiev Wave Theory. These waves are clearly evident during periods that witnessed major technological transformations such as the Industrial Revolution, the spread of electricity, the rise of the oil and automobile industries, and up to the contemporary digital revolution. The findings also show that periods of economic expansion are often associated with the diffusion of technological innovations and increases in investment and productivity, while recessionary periods coincide with financial crises and economic restructuring.

The study concludes that technological innovation represents the pivotal factor in launching long-term waves of economic growth in the U.S. economy, and that current transformations related to artificial intelligence, the digital economy, and renewable energy may signal the beginning of a new economic wave in the coming decades, which could lead to a reshaping of the global economic structure.

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1. Introduction

Economic cycles are considered fundamental topics in macroeconomics, as researchers since the nineteenth century have attempted to explain the causes of oscillation between periods of growth and recession in the capitalist economy. Among the most prominent theories addressing this phenomenon is the Kondratiev Wave theory proposed by the Russian economist Nikolai Kondratiev in the 1920s. This theory suggests that the global economy undergoes long-term cycles ranging between forty and sixty years, during which phases of economic expansion alternate with periods of contraction and economic slowdown [1].

This theory has gained significant importance in historical economic studies because it links technological development with major economic transformations. It is believed that each long economic wave is associated with the emergence of a cluster of technological innovations leading to the expansion of production and investment, then enters a saturation phase before the economy begins to slow down and a new economic crisis emerges [2].

The **United States of America** is considered one of the best case studies for applying this theory, due to its central role in leading industrial and technological transformations since the end of the nineteenth century. The U.S. economy has experienced several phases of rapid growth associated with industrial and technological innovation, starting from the Second Industrial Revolution and up to the contemporary digital revolution.

This study aims to analyze the evolution of the U.S. economy according to the framework of Kondratiev Waves, by reviewing the main economic waves and linking them to the technological and institutional changes witnessed by the United States over the past two centuries.

Research Objectives

This research aims to analyze and interpret long-term economic cycles in the U.S. economy in light of the long wave theory proposed by the Russian economist Nikolai Kondratiev, and to apply Kondratiev's theory to the U.S. economy as a prospective study, by achieving a set of scientific and economic objectives, the most important of which are:

1. Analyze the theoretical framework of Kondratiev Wave Theory and clarify the intellectual and economic foundations upon which it was based, while tracing its development in economic literature since its emergence in the 1920s.
2. Identify the characteristics of long-term economic cycles according to Kondratiev's theory, and explain the factors leading to the emergence of these waves, such as technological innovation and structural shifts in the global economy.
3. Analyze the historical evolution of the U.S. economy from the beginning of the nineteenth century until 2025, focusing on changes in Gross Domestic Product and economic activity during this period.
4. Test the applicability of Kondratiev Wave Theory to the U.S. economy by analyzing long-term economic data and discovering cyclical patterns in economic growth.
5. Study the relationship between long economic waves and the major technological revolutions witnessed by the U.S. economy, such as the Second Industrial Revolution and the Information Technology Revolution.

6. Identify the different phases of Kondratiev Waves in the U.S. economy, and link them to major economic events such as financial crises and world wars.
7. Provide an economic explanation for long-term fluctuations in the U.S. economy, and explain the role of innovation, investment, and institutional changes in shaping these cycles.
8. Forecast future trends of the U.S. economy in light of Kondratiev Wave Theory, and assess the possibility of the emergence of a new economic wave associated with modern technologies such as artificial intelligence and the digital economy.

Research Hypotheses

Based on the theoretical framework proposed by the Russian economist Nikolai Kondratiev regarding long-term economic cycles, this research seeks to test a set of scientific hypotheses related to the evolution of the U.S. economy, which can be formulated as follows:

Hypothesis One: Kondratiev's theory can be applied to the U.S. economy; therefore, the current growth cycle in the U.S. economy will be directly followed by a recession cycle.

Hypothesis Two: The US economy has long-term economic cycles that last between 40 and 60 years, which is consistent with what the Kondrati Wave Theory suggests.

Hypothesis Three: Periods of economic expansion in the US economy are associated with the emergence of major technological revolutions that have led to increased investment, productivity, and economic growth.

Hypothesis Four: Contraction phases in Kondratic waves see an increase in economic and financial distress in the US economy compared to periods of economic expansion.

Hypothesis five: Structural changes in the US economy, such as changes in technology, industry and energy, affect the formation of long-term economic waves.

Hypothesis Six: Major changes in the US economy coincide with changes in the global economic system, suggesting that Kondratic waves are global and not just local.

Hypothesis Seven: The global economy may enter a new economic wave at the beginning of the twenty-first century associated with the digital economy and advanced technological development.

Study Questions
This research seeks to answer a set of scientific questions that help understand the nature of long-term economic cycles in the U.S. economy in light of the theory proposed by the Russian economist Nikolai Kondratiev. These questions can be formulated as follows:

Main Question

To what extent can Kondratiev Wave Theory be used to explain the historical economic cycles in the U.S. economy and forecast its future trajectories in light of waves of innovation and economic transformation?

Sub-questions

1. What are the theoretical foundations upon which Kondratiev Wave Theory is based in explaining long-term economic cycles?

2. What are the main characteristics of the long economic waves identified by Kondratiev, and what factors lead to the emergence of these waves?
3. Does the Gross Domestic Product (GDP) data in the United States show long cyclical patterns corresponding to the time duration of Kondratiev Waves (40-60 years)?
4. What is the relationship between long economic waves and the major technological revolutions witnessed by the U.S. economy?
5. How can modern standard methods such as Fourier Transform and Wavelet Analysis be used to detect long economic waves in GDP data?
6. What are the most important economic and historical events that coincided with the upswing and downswing phases of Kondratiev Waves in the U.S. economy?
7. Do current economic trends indicate the possibility of the global economy entering a new economic wave during the twenty-first century?

Study Limitations

The study limitations are:

- Dependence on historical data whose accuracy may vary in older periods.
- Potential influence of exceptional events such as world wars and financial crises.
- Difficulty in completely separating long-term economic cycles from other econom

Research Methodology

1. Research Approach

This research relies on a combination of the descriptive-analytical approach and the econometric approach to study long-term economic cycles in the U.S. economy. The descriptive approach aims to analyze the theoretical framework of Kondratiev Wave Theory proposed by the Russian economist Nikolai Kondratiev, while the econometric approach is used to test the existence of these waves in the actual economic data of the U.S. Gross Domestic Product during the period from 1800 to 2025.

2. Data Sources

The research relies on long-term time series data of real Gross Domestic Product in the United States, obtained from approved historical economic databases, such as:

- Bureau of Economic Analysis
- Federal Reserve Economic Data (FRED)
- Maddison Project Database

This data is used to form a long time series allowing the analysis of economic patterns spanning two centuries.

3. Statistical and Econometric Analysis Tools

To test the hypothesis of the existence of long economic waves in the U.S. economy, the research relies on a set of advanced econometric tools in time series analysis, most notably:

A. Spectral Analysis

Spectral analysis is used to detect cyclical frequencies in economic time series, as it allows identifying economic cycles ranging between 40 and 60 years, the duration suggested by Kondratiev Wave Theory.

B. Fourier Analysis

This analysis is used to transform the GDP time series into the frequency domain to detect long-term cyclical patterns in economic data.

Several recent studies have used spectral and time series analysis techniques to detect long-term economic cycles in the global economy, where the analysis results showed cycles ranging between 40 and 60 years, which corresponds to the Kondratiev wave hypothesis [3].

C. Wavelet Analysis

The research also relies on this technique, which allows analyzing cyclical changes in economic data over time, helping to identify the periods in which long economic waves appear.

D. Econometric Analysis Steps

The econometric analysis in this research involves several main stages:

1. Collecting U.S. GDP data for the period (1800-2025).
2. Transforming data into logarithms to reduce variance in the time series.
3. Removing the general trend of economic growth to separate the long-term trend from cyclical fluctuations.
4. Comparing the extracted results with known historical periods of Kondratiev Waves.

E. Econometric Analysis Model

The economic model used in the study can be expressed as follows:

$$GDP_t = \alpha + \beta t + \sum_{i=1}^n \gamma_i \sin(\omega_i t) + \sum_{i=1}^n \delta_i \cos(\omega_i t) + \varepsilon_t$$

Where:

3.1. GDP_t	3.2. GDP at time t
3.3. t	3.4. Time
3.5. ω	3.6. Frequency associated with economic cycles
3.7. ε_t	3.8. Random error

2. Theoretical Framework of Kondratiev Wave Theory

First: Introduction to Nikolai Kondratiev

Background and Scientific Formation

Born in 1892 in the Russian Empire, Nikolai Kondratiev grew up in a rural social environment before studying economics at Saint Petersburg University. During his studies he was influenced by the historical school of economics and statistical research related to economic cycles. This scientific background helped him develop an interest in using quantitative methods to analyze long-term economic data and study the development of industrial capitalism [4].

Contributions to the Study of Economic Cycles

In the 1920s, Kondratiev began studying long-term changes in the global economy by analyzing data on production, prices, and interest rates in major industrial countries. He observed the existence of long economic cycles extending between forty and sixty years, in which periods of economic expansion alternated with periods of recession. This discovery formed the basis of what later became known as the theory of long waves in economics [5].

Development of the Long Wave Theory

Kondratiev's research showed that the capitalist economy does not only move in short cycles like business cycles but also undergoes long cycles associated with structural changes in technology and investment. He pointed out that these long waves are usually associated with the emergence of major industrial innovations such as railways and electricity, which lead to widespread economic expansion before reaching a saturation phase[6].

Influence of His Ideas on Economic Thought

Kondratiev's theory significantly influenced a number of later economists, especially the Austrian economist Joseph Schumpeter, who linked long economic waves to processes of technological innovation. Schumpeter considered that long waves arise as a result of the emergence of clusters of basic innovations that change the structure of the global economy and launch new waves of growth [7].

His Role in the Soviet Economy

Alongside his academic work, Kondratiev held important positions in economic institutions in the Soviet Union during the 1920s, where he participated in preparing economic policies and studying agricultural and industrial development. He also founded the Institute for the Study of Economic Cycles in Moscow, which was an important center for economic research at that time [8].

Conflict with the Political System

Kondratiev faced sharp criticism from the Soviet authorities in the late 1920s, as his theory about the long cycles of capitalism was considered contradictory to the official Marxist vision, which expected the collapse of the capitalist system. As a result, he was arrested in 1930 during the political repression campaigns under Stalin and was executed [9].

His Scientific Legacy and Contemporary Influence

Despite his death in 1938 during the Stalinist repressions, Kondratiev's works later became an important part of the economic literature on long-term cycles. Today, his theory is used in studies of historical economics and technological economics to analyze major

transformations in the global economy, especially in explaining the relationship between technological innovation and long-term economic growth [10].

Previous Predictions of the Theory

He was able to predict the Great Depression of 1929-1939 as early as 1922, seven years before it began, outperforming the predictions of prominent Austrian economists Ludwig von Mises and Friedrich von Hayek, who warned of the next great crisis during 1925-1929.

In addition to the theory's accurate prediction of the collapse of the Soviet Union in 1991 with great precision.

Scientists today classify five long waves attributed to N. Kondratiev. Based on the study of the works of nineteen scientists, T. P. Bliznyuk classified the waves and calculated their periods (Table 1) [11].

Table (1): Estimates of Kondratiev Long Waves by Different Scholars (Starting Points and Peak Years)

	Scientist	Year	The Kondratiev wave									
			1st		2nd		3d		4th		5th	
			Be- gin- ning	Peak	Be- gin- ning	Peak	Begin- ning	Peak	Begin- ning	Peak	Begin- ning	End of t he wave
1	M. Kondratiev	1925	1790	1817	1851	1875	1896	1920				
2	A. Spithof	1925		1822	1874	1895	1912					
3	De Wolf	1929		1825	1849	1873	1896	1913				
4	J. Schumpeter	1939	1787	1813	1842	1869	1897	1924				
5	J. M. Clark	1944		1850	1875	1900	1929					
6	Dupre	1978	1789	1808	1846	1872	1895	1920	1939/46		1974	
7	W. Rostow	1980	1790	1815	1848	1873	1896	1920	1935	1951	1972	
8	Mandel	1980		1826	1847	1873	1893	1913	1939/48		1967	
9	Van Dyne	1983			1845	1872	1892	1929	1948		1973	
10	M. Riccione	1985	1769	1799	1816	1849	1873	1897	1921	1946	1973	
11	S. Glazyev	1993	1770		1830		1880		1930		1985	
12	I. Lipsits, A. Neschadyn	1997	1785	1835	1830	1890	1880	1940	1930	1990	1985	2035
13	Y. Yakovets	1999									1974	1998
14	V. Efremov	1999	1785	1845	1846	1900	1901	1950	1951	1990	1991	2020
15	N. Mironenko	2001	1785	1813	1847	1872	1893	1917	1945	1969	1985	
16	O. Gritsay, G. Jof- fe, A. Trevisch		1770		1830		1880		1930		1970	
The results of the calculations												
	Average		1782	1822	1845	1878	1894	1922	1937	1969	1977	2016
	Duration (Du- ration between the Beginnings)			(63)		(49)		(43)		(40)		(39)*
	Duration (Du- ration be- tween the Peaks)				(56)		(44)		(47)		(40)*	

This table presents a comparative overview of various scholars' estimates regarding the timing of Kondratiev long economic waves, including their starting points and peak years. It highlights

noticeable variations among researchers in identifying the exact dates of each wave; however, there is a general consensus that these cycles span approximately 40 to 60 years. The table also includes calculated average values for wave beginnings and peaks, as well as the average duration of each cycle. These findings support the core hypothesis of Kondratiev Wave Theory, which suggests that capitalist economies evolve through long-term cyclical patterns driven primarily by technological innovation and major structural transformations in the global economy

Second: Introduction to the Theory

1. Definition of the Cycle

Several definitions of the cycle have emerged, the most important of which was the definition developed by Arthur Burns and Wesley Mitchell, which states that the cycle "consists of expansions followed by contractions that occur at about the same time in many sectors, followed by periods of economic recession, then a widespread recovery that would generate an expansion phase in the next cycle[12].

However, other researchers have viewed this phenomenon not as an "economic cycle" but as "economic fluctuation" based on the phase of turbulence and irregularity that characterizes it. The most prominent thinker to describe it as such was Robert Lucas in 1972, who expressed it as "the cyclical movements do not exhibit perfect regularity either in amplitude or in frequency; the observed disturbances concern changes in a series of different aggregates," and he was supported in this by the French thinker Plosser in 1989[13].

1. Concept of Long Economic Waves

The theory of long economic waves is one of the most important theories that attempted to explain long-term economic fluctuations in the capitalist system. This theory was proposed by the Russian economist Nikolai Kondratiev in the 1920s, indicating that the capitalist economy does not only undergo short cycles such as business cycles, but also undergoes long cycles extending between forty and sixty years. These cycles are characterized by two main phases: the phase of economic expansion and the phase of contraction or recession.[¹⁴] Kondratiev generalized the study of the dynamics of certain economic indicators, particularly interest rates, production and consumption volumes of coal, pig iron, and lead, as well as prices of raw materials, agricultural and industrial products, and identified the existence of cycles ranging between 45 and 60 years[14].

Nikolai Kondratiev studied economic indicators in the most advanced countries of his time, namely England, France, Germany, and the United States. His analysis was based on economic data covering the period between 1780 and 1920. Through this analysis, he concluded the existence of two complete long economic cycles and the beginning of a third cycle. According to Kondratiev's estimates, the first cycle extends approximately from the period 1789-1803 to 1841-1843, while the second cycle extends from 1844-1851 to 1890-1896[15].

Nikolai Kondratiev linked the cyclical nature of economic developments primarily to technological changes that bring about profound transformations in the structure of production. However, his explanation was not limited to the technological factor alone; he also considered a range of other factors, such as wars and revolutions, the emergence of

new countries on the world political map, in addition to fluctuations in gold production and their impact on the monetary system [16].

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Kondratiev viewed that the primary empirical evidence for his theory was the synchrony between the general rise in economic indicators and the beginning of a new long wave, which he considered an indicator of qualitative changes in economic conditions. On this basis, he linked the first long wave to the spread of the steam engine and the great expansion in the textile industry, both of which contributed to a boom in industrial production [18].

As for the second wave, he attributed it to the emergence and development of the steel industry, in addition to the expansion of the railway network, which allowed the transport of people and goods on a large scale, thereby supporting the acceleration of economic growth in that phase. However, this interpretation of the nature of long waves was subject to criticism in subsequent economic literature, as some researchers questioned the sufficiency of the technological factor alone to explain the phenomenon and pointed to the need to integrate broader economic and institutional factors into the analysis of these cycles [19].

Proceeding from the core idea proposed by Nikolai Kondratiev, a number of researchers in contemporary economic literature tend to consider the depression phase as the starting point for a new long economic wave. During periods of declining production and economic activity, pressures increase on economic institutions to make substantial improvements in production methods, which drives the adoption of basic innovations capable of revitalizing the economic process and preparing the conditions for a subsequent growth phase [20].

When applying improving innovations, development efforts are primarily concentrated within the economic enterprise itself, where production processes are improved and efficiency is increased. The adoption of these innovations contributes to stimulating economic activity, leading to a prosperity phase representing the upswing phase of the long economic cycle [21].

However, the series of improvements associated with the application of improving innovations eventually reaches its maximum limits on both the supply and demand sides. At this point, the economy reaches its peak growth, representing the crest of the wave and the turning point in the economic cycle. After that, economic performance gradually declines until it enters a critical phase [22].

In this phase, the potential of improving innovations is exhausted, necessitating the introduction of basic innovations capable of bringing about fundamental transformations in the structure of production and technology. During this period, a gap emerges between old technologies that are no longer able to support high growth rates and new technologies that have not yet crystallized as an effective source of economic growth [23].

This situation usually leads to an economic recession, which in turn stimulates processes of innovation and technological renewal. Over time, these innovations gradually begin to diffuse within the economy, contributing to the improvement of economic indicators in the long term and paving the way for the emergence of a new long economic wave [24].

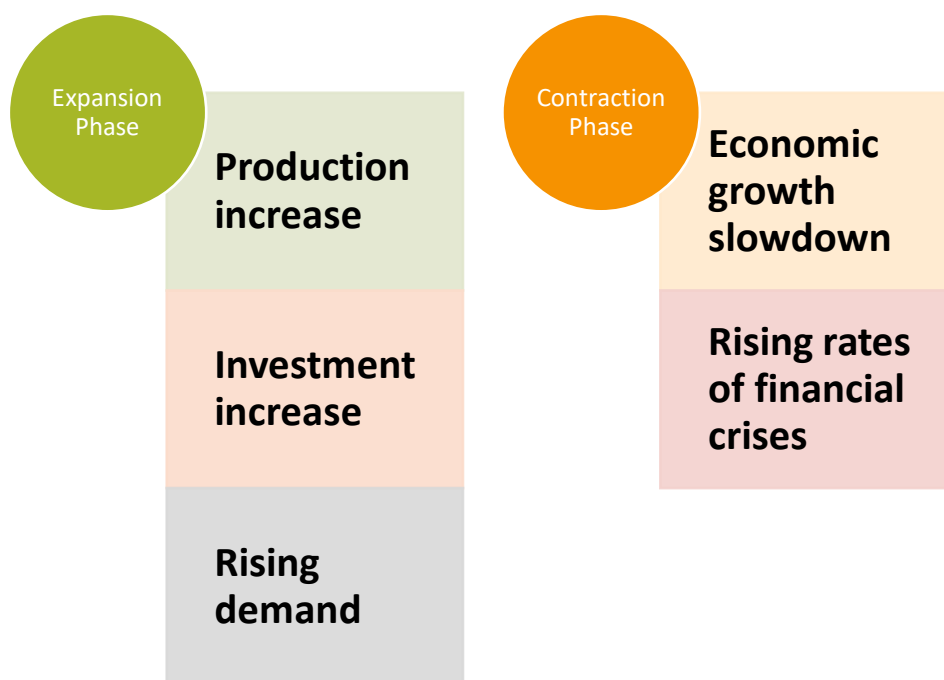
2. Basic Characteristics of Kondratiev Waves

Economic studies indicate that Kondratiev Waves are characterized by several basic features, most importantly their long duration and their association with structural changes in the global economy. These waves are also characterized by successive phases of rapid economic growth followed by a relatively long economic slowdown. Researchers have observed that these waves appear clearly in data on prices, industrial production, and international trade [25].

3. Phases of the Long Economic Wave

Kondratiev Waves are usually divided into two main phases: the upswing phase, characterized by increased production, investment, and rising demand, and the downswing phase, which witnesses a slowdown in economic growth and a rise in the rate of financial crises. Some studies indicate that these phases are closely linked to technological changes and structural transformations in the global economy [26].

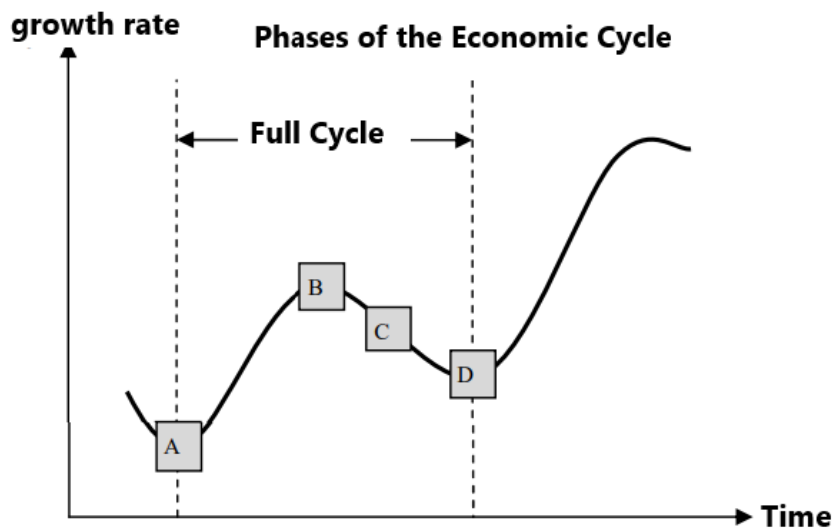
Fig (1): Kondratiev Waves



However, some economic thinkers divide the phases into 4 phases: (a) Economic recovery phase: characterized by a tendency for the general price level to stabilize, economic activity increases slowly, inventories decline, and orders increase. (b) Boom phase: characterized by a steady rise in prices, a rapid increase in production volume, accompanied by an increase in income and employment levels. (c) Contraction phase:

prices begin to fall, production and income decrease, unemployment increases, and inventories accumulate. (d) Depression phase: the most dangerous phase if not controlled, potentially leading to an economic crisis, where unemployment spreads, trade and economic activity generally stagnate, prices may fall, and economic growth rates become negative [27].

Fig (2): Phases of The Economic Cycle



4. Illustrative Model of Long Economic Cycles

The nature of long economic waves can be illustrated through a simplified model of economic cycles, where capitalist economies undergo successive periods of growth and recession extending over several decades. For example, periods of economic expansion can be observed, such as the period (1890-1930) and another period (1970-2010), corresponding to periods of relative recession such as (1930-1970) and the slowdown phase that began after the global financial crisis of 2008. It must be emphasized that the exact dates of the waves vary among researchers, as Kondratiev estimates the duration of the economic cycle at about 40-60 years.

5. Characteristics of Economic Cycles

The characteristics of economic cycles are evident as follows: [28].

1. Recurrence: They are renewable and occur periodically.
2. Diffusion and comprehensiveness: This is evident in their impact on a very large number of economic activities, and thus they can also be described as having a general and comprehensive nature.
3. The cycle usually passes through four basic phases.

4. Variation in the type of cycles, and consequently variation in the amplitude and duration of the cycle.
5. There are cases where two cycles overlap with each other, meaning the containment of small cycles within a large cycle.
6. The causes of cycles differ from one cycle to another.

4. The Relationship between Economic Waves and Technological Innovation

Many economists see technological innovation as the primary driver of Kondratiev Waves. The economist Joseph Schumpeter developed this concept by linking long economic cycles to the emergence of clusters of technological innovations that lead to profound transformations in the economy, such as the Industrial Revolution or the Information Revolution [29].

5. Economic Waves and Industrial Revolutions

Numerous studies indicate that each long economic wave has been associated with a major industrial or technological revolution. For example, the first wave was associated with steam technology, while the second wave was associated with railways and steel, whereas the third wave was associated with electricity and heavy industries. The fourth wave was associated with oil and the automobile industry, while the fifth wave was associated with information and communication technology [30].

6. Econometric Analysis of Long Economic Waves

With the development of econometrics, researchers began using time series analysis methods to detect long-term economic waves. Various techniques have been used, such as spectral analysis and Fourier Transform analysis to detect cyclical frequencies in economic data, in addition to using Wavelet Analysis to analyze changes in these cycles over time [31].

7. Scientific Debate Surrounding the Theory

Despite the widespread use of Kondratiev Wave Theory in economic literature, it remains a subject of debate among economists. While some researchers believe that historical and statistical evidence supports the existence of these waves, others question the possibility of regular economic cycles of such length due to the influence of changing political and technological factors [32].

8. Importance of the Theory in Analyzing the Contemporary Economy

Kondratiev Wave Theory continues to be used in modern economic studies to analyze long-term transformations in the global economy. This theory has become an important analytical tool for understanding the relationship between technological innovation and economic growth, especially in light of transformations associated with the digital economy and artificial intelligence [33].

Kondratiev Wave Theory is based on the idea that the capitalist system does not develop in a stable, linear fashion, but undergoes long cycles of economic growth and decline. Kondratiev based his analysis on historical data related to production, prices, and interest rates in major industrial countries during the nineteenth and twentieth centuries [34].

The theory suggests that the long economic cycle typically consists of two main phases:

1. Economic Expansion Phase

This phase is characterized by high rates of investment, increased industrial production, and the spread of new technological innovations. It is also characterized by increased demand for labor, rising wages, and improved living standards.

2. Economic Contraction Phase

This phase begins when technological innovations reach a saturation point, leading to a decline in investment rates, a slowdown in economic growth, and the emergence of financial crises.

The economist Joseph Schumpeter developed Kondratiev's theory by linking it to the concept of technological innovation, considering that long economic waves arise as a result of the emergence of "clusters of basic innovations" that lead to the emergence of new industrial sectors driving economic growth [35].

Many researchers emphasize that these waves are not only related to the economy but also encompass broad social and political changes, including shifts in the global system and the balance of economic power among nations [36].

Nevertheless, studies conducted by T. P. Bliznyuk indicate the existence of fundamental differences in determining the starting and peak points of the economic wave.

2.1. Models of Cyclical Phases

This model relies on analyzing the dynamics of economic output (i.e., Gross Domestic Product) of the economic system. Output is determined according to the production function, which illustrates the relationship between the quantity of goods and services produced and the production resources of labor and capital. Output is allocated to satisfy consumption and investment, where investments are used to compensate for the depreciation of fixed capital and to increase capital stock, thereby increasing productive capacity [37].

Table (2): Definitions of Economic Variables and Their Symbolic Notations in the Model

3.9. Gross Domestic Product (GDP)	3.10. Y
3.11. Labor resources	3.12. L
3.13. Capital	3.14. K
3.15. Consumption	3.16. C
3.17. Investment	3.18. I

There is a positive correlation between investments and changes in demand and prices, as prices rise with increasing unmet demand, leading to economic disequilibrium. Since the economic system seeks to restore equilibrium, damped oscillations appear in this process. Conversely, shortening response time periods allows the system to return to equilibrium more quickly when facing disturbing factors [38].

The recession phase, i.e., the state of equilibrium with the absence of economic growth, is a natural state for the system, but it is unsatisfactory for economic actors because profit levels are low and capital is not utilized efficiently. Entrepreneurs often hesitate to invest due to high risks and costs, as the producer may not find sufficient demand, leading to potential losses. Investors usually wait for market signals before embarking on investments [39].

The main signal is increased demand for certain products or sectors, such as infrastructure, real estate, or innovative goods using modern technologies. Meeting this demand is initially financed through accumulated funds in the economy (recovery phase), then reinforced by relying on loans. Independent demand supported by the credit system drives investment in profitable sectors, leading to comprehensive economic growth (prosperity phase) [40].

Due to the lag in the effect of investments and the establishment of new production units relative to changes in demand, after a period, a state of demand saturation and the beginning of its decline appears, while productive capacity continues to expand due to speculation and optimistic expectations. This leads to a sharp economic crisis, where asset and resource prices fall, credit supply decreases, bankruptcies occur, and productivity declines (decline phase). After that, the economy enters a new recession phase, with no growth until a new demand "shock" appears [41].

This situation differs from the pre-crisis phase, as the economy acquires a qualitatively new form: innovative industries emerge, modern technologies are introduced, and new needs are generated reflecting structural transformations in the market.

The final model, the growth rate (economic growth rate), is an indicator denoting the rate of economic development. It can be calculated using the following formula:

$$g = [(Y_t - Y_{t-1}) / Y_{t-1}] * 100\%$$

Y_t - an indicator of real GDP of the current year;

Y_{t-1} - an indicator of real GDP in the previous year.

Historical Development of Kondratiev Wave Theory in Economic Literature

Emergence of the Theory in Modern Classical Economics

The theory of long waves emerged in the 1920s when the Russian economist Nikolai Kondratiev published his famous study on long-term economic cycles. Kondratiev relied on a statistical analysis of price, production, and interest rate data in major industrial economies since the nineteenth century and observed the existence of economic cycles extending between forty and sixty years. He considered these cycles to represent a structural pattern in the development of the capitalist economy [42].

Development of the Theory in the School of Economic Innovation

In the 1930s and 1940s, the Austrian economist Joseph Schumpeter developed Kondratiev's theory and linked it to processes of technological innovation. He argued that long economic waves arise as a result of the emergence of clusters of basic innovations that

lead to structural transformations in the economy, such as the Industrial Revolution or the spread of electricity. Schumpeter considered innovation to be the primary driver of long economic cycles [43].

Interest in the Theory after World War II

After World War II, Kondratiev's theory received increasing attention in economic literature, especially in historical economic studies. A number of researchers analyzed long-term economic data to verify the existence of these cycles. Some studies showed the presence of long cyclical patterns in industrial production and world trade, which revived the debate on the validity of the theory [44].

Emergence of Modern Statistical Analyses

With the development of quantitative methods in economics during the second half of the twentieth century, researchers began using spectral and time series analysis techniques to test the long wave hypothesis. Some studies indicated the presence of economic cycles ranging between 45 and 60 years in global output data [45].

Linking Waves to Technological Changes

Recent studies have focused on the relationship between Kondratiev Waves and major technological transformations. Research has shown that each long economic wave has been associated with a specific technological revolution, such as railways, electricity, or information technology. This research direction suggests that technological innovation represents the fundamental factor in launching long-term waves of economic growth [46].

Applying the Theory to the Global Economy

In recent decades, Kondratiev's theory has been applied to the analysis of the global economy, as researchers have attempted to identify economic waves from the Industrial Revolution to the contemporary digital economy. Some studies have shown that the global economy has entered a new wave associated with the digital revolution and advanced technology [47].

Scientific Debate Surrounding the Theory

Despite its prevalence in economic studies, Kondratiev's theory remains a subject of debate among economists. While some researchers believe it provides a useful framework for understanding long-term economic transformations, others question the existence of fixed cycles of such length due to the influence of changing political and technological factors. Nevertheless, the theory continues to be used in the fields of historical economics and innovation studies [48].

3. Historical Waves of Kondratiev's Theory

Researchers usually divide Kondratiev Waves into five main economic waves since the beginning of the Industrial Revolution:

First Wave (1780-1840)

This wave was associated with the First Industrial Revolution and the spread of the use of the steam engine in industry and transport. These innovations led to a significant increase in industrial production and the emergence of modern factories [49].

Second Wave (1840-1890)

This phase was characterized by a great expansion in railway networks and the development of heavy industries, particularly the steel industry, along with notable progress in communication means such as the telegraph. These technological innovations contributed to enhancing transport and trade movements and connecting regional markets, which accelerated the process of industrialization in both Europe and the United States. These developments also helped increase industrial production and expand investments and infrastructure, making this period one of the pivotal phases in the development of industrial capitalism according to the analysis of Kondratiev's long waves [50].

Third Wave (1890-1945)

This wave witnessed the spread of electricity, chemical industries, and heavy industries, leading to a radical transformation in the global industrial economy [51].

Fourth Wave (1945-1990)

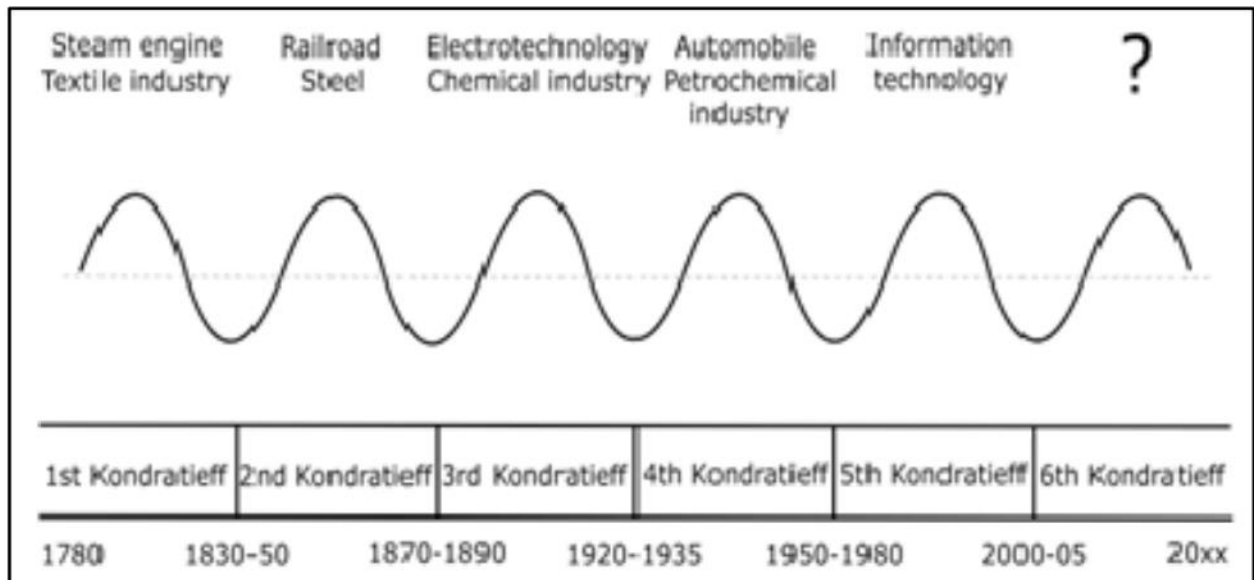
This wave was associated with the spread of the oil industry, automobile industry, and mass production after World War II [52].

Fifth Wave (1990-Present)

This phase is characterized by the emergence of the digital economy and the spread of the internet and digital technology.

Many researchers believe that these waves are closely linked to the major technological transformations that change the structure of the global economy [53].

Fig (3) The long waves of economic development



This figure illustrates the sequence of Kondratiev long waves in the global economy, highlighting their cyclical nature over time. Each wave is associated with a dominant technological paradigm that drives economic growth and structural transformation. The first wave is linked to the steam engine and textile industry, followed by railways and steel in the second wave, electrotechnology and chemical industries in the third, and the automobile and petrochemical industries in the fourth. The fifth wave is driven by information technology and digital innovation. The figure also suggests the emergence of a

potential sixth wave, likely associated with advanced technologies such as artificial intelligence, renewable energy, and biotechnology. Overall, the diagram reflects the recurring pattern of expansion and contraction phases that typically span 40 to 60 years, supporting the core premise of Kondratiev Wave Theory.

Source: Nefiodow and Nefiodow 2014.

The end of the twentieth century and the beginning of the twenty-first century witnessed a widespread diffusion of information and communication technologies, along with the shift from analog data transmission methods to digital ones. These technological transformations have been associated with the beginning of what is referred to as the sixth long wave and the emergence of the features of the Fourth Industrial Revolution known as Industry 4.0. Some estimates in the economic literature suggest that this wave approximately extends during the period between 2018 and 2042 [54].

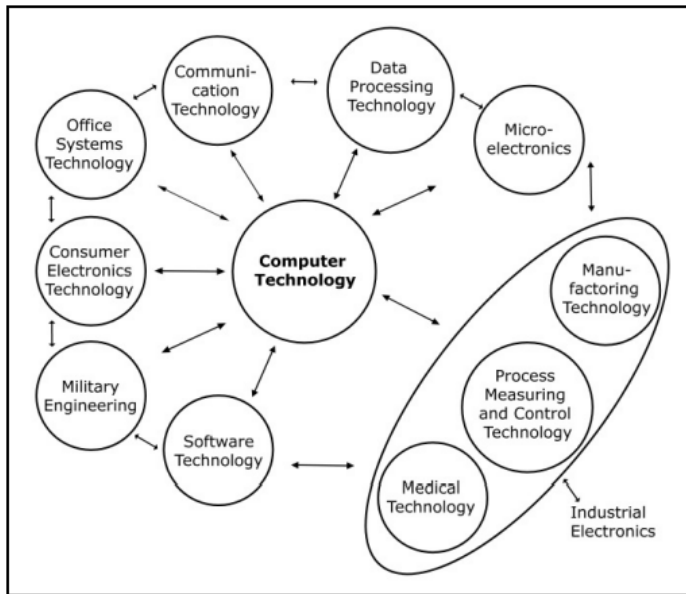
With the expansion of digitalization applications, it has become possible to develop the concept of the smart enterprise, where machines, production systems, supply chains, and logistics systems integrate into an interconnected system capable of interacting with each other with a high degree of autonomy. In such a production model, most operations are carried out automatically, while the human role is limited to monitoring, supervision, and intervention when necessary to adjust performance or address malfunctions [55].

In this context, the importance of studying the characteristics of the innovation life cycle from the perspective of systems dynamics increases, as digital transformation is seen as a structural turning point that not only affects technological development but also leads to the economic system transcending its traditional stability limits, contributing to the emergence of new organizational and production patterns [56].

It is also worth noting that digital transformation is one of the main axes in economic policies within the European Union, where it is viewed as a key factor supporting economic and social transformations. For this purpose, European countries allocate significant financial resources to enhance digital infrastructure and encourage innovation and adaptation to the requirements of the digital economy [57].

The second criterion: This criterion relates to the economy and consists of identifying the leading industry and the value chain. The leading industry is one that develops newly thanks to the basic innovation and is also the one that benefits most from it. This leading industry acts as the engine for overall economic growth throughout the Kondratieff cycle. During the first Kondratieff cycle, this industry was the textile industry, and during the fifth Kondratieff cycle, it was the information technology industry [58].

Fig. (4) The technological network of the information technology



Source: Nefiodow 1991.

This figure illustrates the technological network centered around computer technology as a core driver of innovation within the information technology paradigm. It shows how computer technology interacts with and supports a wide range of related fields, including communication technology, data processing, microelectronics, software, and consumer electronics. The diagram also highlights the extension of these technologies into industrial applications such as manufacturing, process control, and medical technology, collectively referred to as industrial electronics. This interconnected structure demonstrates how technological advancements diffuse across sectors, reinforcing the role of digital innovation as a key engine of economic growth in the modern Kondratiev wave.

To better understand the temporal structure of Kondratiev long waves, it is essential to examine their internal phases and chronological boundaries. Researchers typically divide each long wave into two main phases: an upswing phase characterized by economic expansion, rising investment, and technological diffusion, and a downswing phase marked by economic slowdown, structural adjustments, and increased financial instability. The identification of these phases relies on historical economic data and varies slightly across studies. The following table presents a synthesized overview of the main Kondratiev waves, their respective phases, and the estimated dates for their beginnings and endings as identified in the economic literature.

Table (3) Long waves and their phases identified by Kondratieff.

3.19. Long wave number	3.20. Long wave phase	3.21. Dates of the beginning	3.22. Dates of the end
3.23. One	3.25. A: upswing	3.26. "The end of the 1780s or beginning of the 1790s"	3.27. 1810–1817

	3.28. B: downswing	3.29. 1810–1817	3.30. 1844–1851
3.31.	3.33. A: upswing	3.34. 1844–1851	3.35. 1870–1875
3.32. Two	3.36. B: downswing	3.37. 1870–1875	3.38. 1890–1896
3.39.	3.42. A: upswing	3.43. 1890–1896	3.44. 1914–1920
3.40. Three	3.45. B: downswing	3.46. 1914–1920	
3.41.			

Source: Andrey Korotayev *, Julia Zinkina, Justislav Bogevolnov, Kondratieff waves in global invention activity (1900–2008), *Technological Forecasting & Social Change, Technological* 78 (2011) 1280–1284, doi: <https://doi.org/10.1016/j.techfore.2011.02.011>

The table provides a structured representation of the successive Kondratiev long waves, clearly distinguishing between their upswing and downswing phases along with their approximate timeframes. It can be observed that each wave follows a cyclical pattern, beginning with a period of economic expansion driven by technological innovation and increased investment, followed by a phase of slowdown characterized by market saturation, declining returns, and structural economic adjustments. Although the exact dates differ slightly among researchers, the overall pattern confirms that these waves typically span several decades, generally within the range of 40 to 60 years. This recurring structure supports the fundamental premise of Kondratiev Wave Theory, which emphasizes the role of long-term technological and economic transformations in shaping the evolution of capitalist economies.

Long wave number Long wave phase Dates of the beginning Dates of the end

Summary of the Section

Economic literature indicates that Kondratiev Wave Theory evolved from a statistical idea about long economic cycles into an analytical framework linking technological innovation and structural transformations in the global economy. Modern econometric methods have contributed to re-evaluating this theory and applying it to contemporary global economic data.

Fig (5): Timeline of Kondratiev Long waves

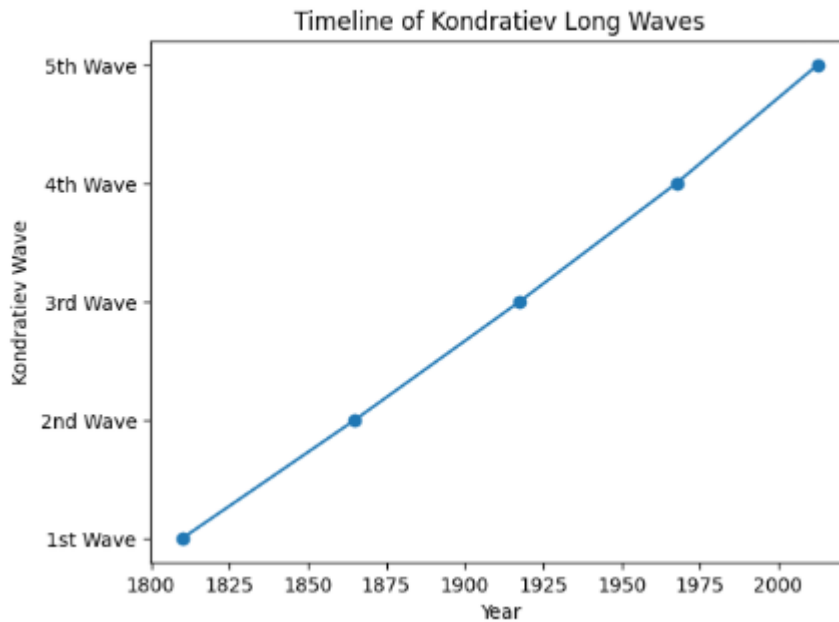


Figure (5) shows the long-term trend of real GDP in the United States during the period between 1800 and 2025. The curve shows a strong upward trend reflecting long-term economic growth, but this growth is interspersed with long cyclical fluctuations corresponding to Kondratiev Waves, which typically last between 40 and 60 years.

Fig (6): Approximate Duration of Kondratiev Waves

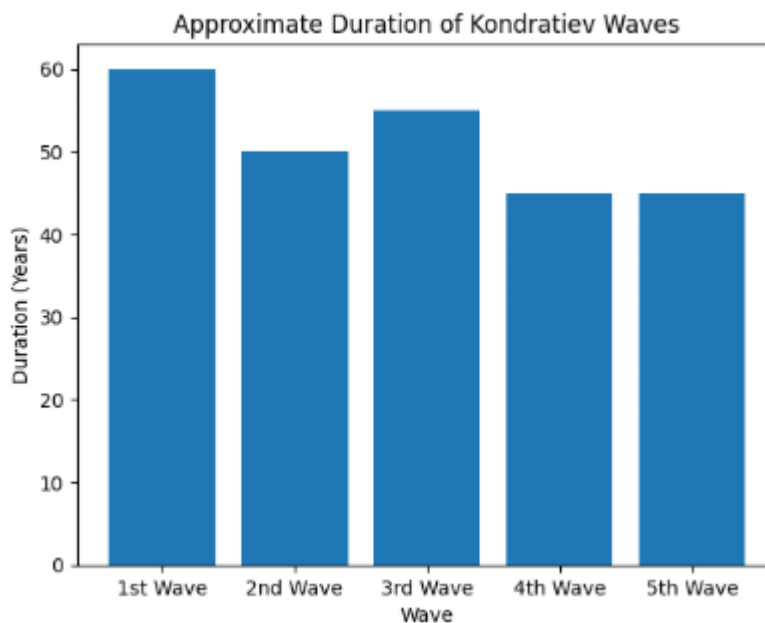


Figure (6) shows the duration of each economic wave, where it appears that the early waves were relatively longer, while modern waves have become shorter due to the acceleration of technological innovation.

To provide a clearer understanding of the evolution of Kondratiev long waves, it is useful to link each wave to its corresponding technological drivers and key economic characteristics. Economic literature emphasizes that each long wave is typically initiated by a cluster of fundamental innovations that reshape production systems, investment patterns, and overall economic structure. These technological transformations serve as the main engine of long-term economic growth and are closely associated with major industrial revolutions. The following table summarizes the main Kondratiev waves, their time periods, the dominant technologies driving each wave, and their key economic features.

Table (4) Kondratiev Waves Table

3.47. Wave	3.48. Period	3.49. Driving Technology	3.50. Economic Features
3.51. First Wave	3.52. 1780--1840	3.53. Steam power and textile industry	3.54. Beginning of the Industrial Revolution
3.55. Second Wave	3.56. 1840--1890	3.57. Railways and steel	3.58. Expansion of heavy industry
3.59. Third Wave	3.60. 1890--1945	3.61. Electricity and chemical industries	3.62. Rise of American industry
3.63. Fourth Wave	3.64. 1945--1990	3.65. Oil, automobiles, and mass production	3.66. Advanced industrial economy
3.67. Fifth Wave	3.68. 1990--2035 (approx.)	3.69. Internet and digital economy	3.70. Knowledge and technology economy

These waves are based on the theory proposed by economist "Nikolai Kondratiev" and later developed by economist "Joseph Schumpeter".

The table demonstrates that each Kondratiev wave is strongly associated with a specific technological paradigm that drives economic transformation. The first and second waves were closely linked to the early stages of industrialization, while the third wave marked the rise of large-scale industrial economies, particularly in the United States. The fourth wave reflects the maturity of industrial capitalism through mass production and the expansion of energy-intensive industries such as oil and automobiles. In contrast, the fifth wave represents a significant shift toward a knowledge-based economy driven by digital technologies and the internet. Overall, the table highlights the central role of technological innovation in shaping long-term economic cycles and supports the view that structural economic change occurs through successive waves of technological advancement.

4. Applying Kondratiev Waves to the U.S. Economy

Third Wave: The Rise of Industrial America (1890-1945)

This wave is considered the turning point where the United States transformed from a relatively agricultural economy to a global industrial power. This period saw the spread of power, chemical industry, heavy industry, as well as the development of large-scale industrial production systems.

One of the most important innovations of this phase was the introduction of the assembly line in factories, especially in the automobile industry led by the Ford Motor Company. This led to an unprecedented increase in industrial productivity, which led to a rapid increase in American industrial production.

However, this phase ended with the Great Depression, one of the greatest economic crises in modern history, in which financial markets collapsed, production levels fell and unemployment rose to unprecedented levels.

Many researchers point out that this crisis represents the end of the expansion phase of the third wave and the beginning of the restructuring phase of the global economy.

Fourth Wave: Advanced Industrial Economy (1945-1990)

After the end of World War II, the American economy experienced a long period of rapid economic growth.

This phase was characterized by several key factors:

- Expansion of the oil and petrochemical industry
- Major expansion in the automotive industry
- Growth of the suburbs and middle class
- Expansion of international trade

During this period, the United States became the world's largest economy, leading the post-war global economic system.

This period also saw the beginning of the information revolution with the rise of computers and the growth of technology companies such as IBM.

This technological shift led to increased productivity and improved economic efficiency in various sectors.

Fifth Wave: Digital Economy (1990-2020)

Since the 1990s, the United States has witnessed a significant shift towards the digital economy, where digital technology and the internet became the main drivers of economic growth.

Giant technology companies like Google, Apple, and Microsoft played a major role in this transformation.

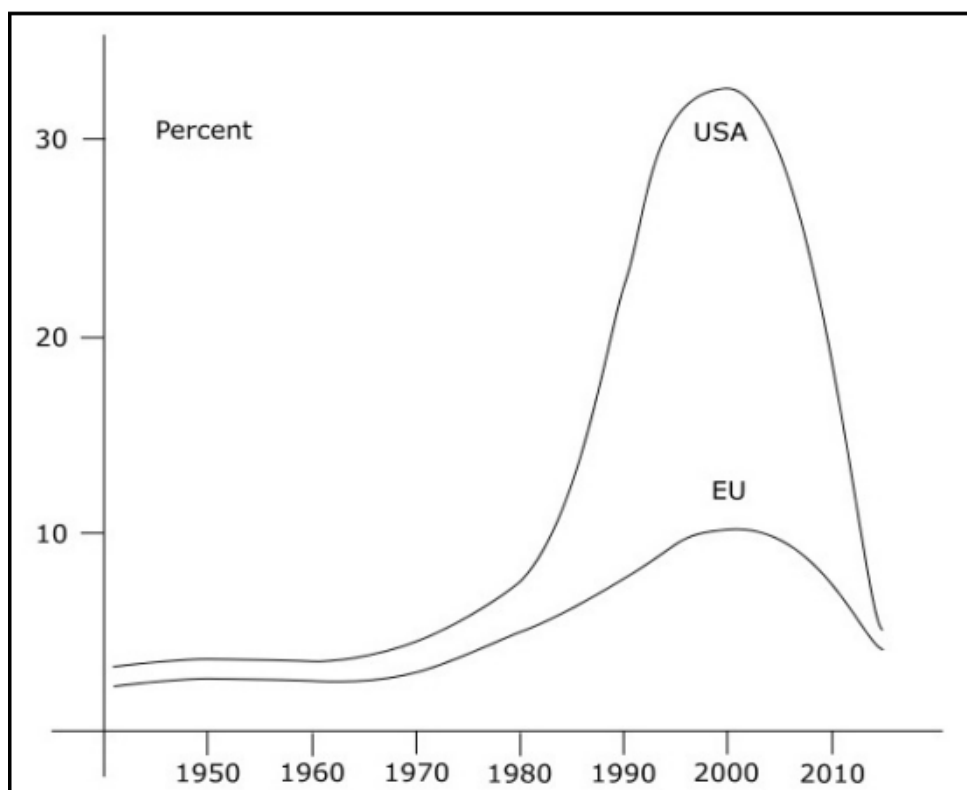
The spread of the internet and e-commerce also led to the emergence of new economic models that changed the nature of global markets.

Some researchers believe that the 2008 global financial crisis represents the beginning of the slowdown phase in this economic wave.

Transition Phase to the Sixth Wave (2020-2025)

Some recent studies suggest that the global economy may be at the beginning of a new economic wave associated with the digital revolution and advanced technological innovations such as artificial intelligence and renewable energy, which is referred to in the economic literature as the sixth Kondratiev wave [59].

Fig (7) Contribution of information technology industry to GNP growth including revenues for telecommunication services



Note: Average values are taken during 3–5 year periods. Value added creation was calculated at 50 % of IT revenue. Source: Nefiodow and Nefiodow 2014.

In the United States, several indicators of this transition can be observed:

1. Artificial Intelligence Revolution: The development of artificial intelligence and big data technologies has become one of the most important drivers of economic innovation.

2. Advanced Digital Economy: The digital economy has expanded to include digital work platforms and the sharing economy.

3. Energy Transition: Increasing investment in renewable energy and clean technology.

4. Reshaping Global Supply Chains: After the Covid-19 crisis, the United States began reorganizing global supply chains and reducing dependence on foreign manufacturing.

Position of the U.S. Economy in the Global System until 2025

As of 2025, the U.S. economy still retains its position as the largest economy in the world in terms of nominal Gross Domestic Product.

This is due to several key factors:

- Strength of technological innovation
- Dominance of global technology companies
- Strength of the U.S. financial system
- Role of the dollar as a global reserve currency

However, the U.S. economy simultaneously faces new challenges such as technological competition with China and transformations in the global economy.

General Conclusion

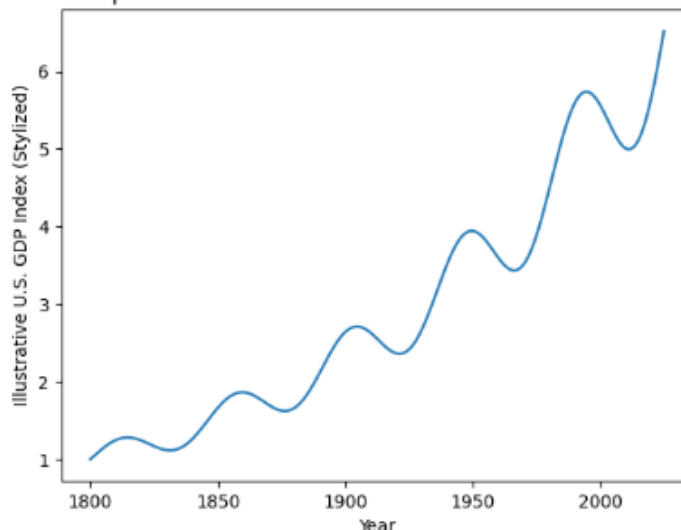
The analysis of the U.S. economy in light of Kondratiev Wave Theory indicates that technological innovation represents the fundamental factor driving long-term economic transformations.

From the Industrial Revolution to the Digital Revolution, the United States has played a pivotal role in leading global economic waves.

With current developments in the fields of artificial intelligence, clean energy, and biotechnology, it is likely that the world is at the beginning of a new economic wave that may reshape the global economic system in the coming decades.

Figure (8): Stylized Relationship Between U.S. Economic Growth and Kondratiev Waves (1800–2025)

Stylized Relationship Between U.S. Economic Growth and Kondratiev Waves (1800–2025)



The figure illustrates the relationship between the long-term growth of the U.S. economy and the long economic waves proposed by the Russian economist Nikolai Kondratiev. The curve shows an upward trend reflecting long-term economic growth, while the cyclical fluctuations reflect economic waves that typically last between 40 and 60 years.

These cycles indicate periods of economic expansion followed by slowdowns or financial crises before the beginning of a new wave of innovation and growth.

5. Economic Crises within Kondratiev Waves

Economic crises play an important role in the transition of the economy from one wave to another. Studies indicate that major recessions often occur at the end of the economic expansion phase.

For example, the Great Depression of the 1930s led to a major shift in U.S. economic policies, as the government adopted broad economic reform programs.

The 2008 global financial crisis also led to a rethinking of the global financial system and the emergence of new monetary policies.

Some researchers see these crises as a necessary turning point for restructuring the economy and preparing the conditions for the emergence of a new technological wave [60].

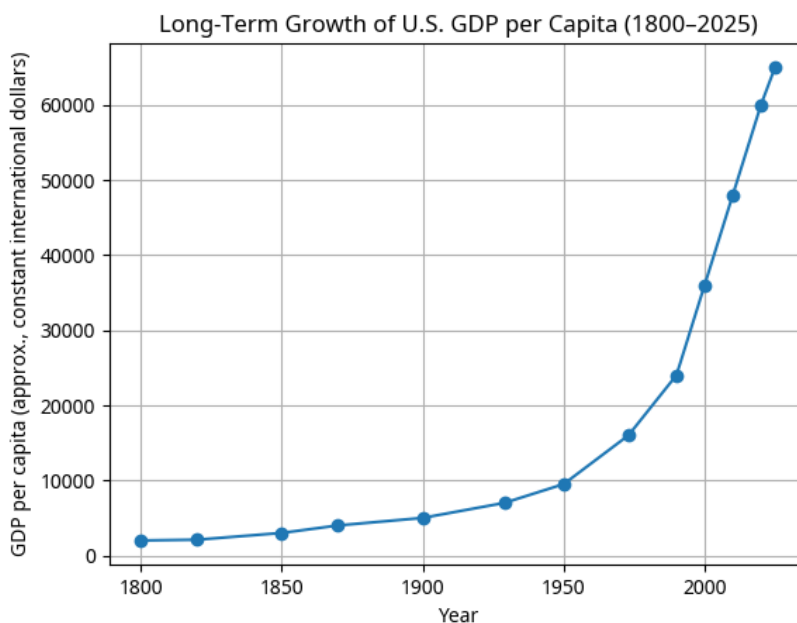
Long-Term Growth of the U.S. Economy (1800-2025)

Economic studies indicate that the average annual growth rate of per capita GDP in the United States since 1800 is approximately 1.6% per year, rising to about 2% after 1950 [61].

This means that the U.S. economy has multiplied several times over the past two centuries as a result of accumulated innovation and industrial expansion.

Data also show that growth was not constant, but went through periods of rapid expansion followed by slowdown, which corresponds to the long wave hypothesis.

Figure (9): Long-term growth of per capita GDP in the United States (1800-2025)



The figure shows the long-term growth of per capita GDP in the United States from the beginning of the nineteenth century until 2025. The curve shows a clear upward trend reflecting continuous economic expansion resulting from technological progress and industrial expansion. However, this general trend is interspersed with long cyclical

fluctuations that can be explained in light of Kondratiev Wave Theory, which indicates the existence of long economic cycles ranging between 40 and 60 years.

Historical Evolution of U.S. GDP

The following table illustrates the evolution of per capita GDP in the United States according to historical estimates (constant dollars):

Table (4): **Historical Evolution of U.S. GDP (1820-2022)**

Year	Per Capita GDP (Approx.)	Economic Change
1820	~\$1800	Agricultural Economy
1870	~\$2400	Early Industrialization
1900	~\$4000	Industrial Revolution
1950	~\$9500	Global Industrial Economy
1973	~\$16000	Post-War Boom
2000	~\$36000	Digital Economy
2022	~\$65000	Knowledge Economy

The table illustrates the long-term evolution of per capita GDP in the United States from 1820 to 2022, highlighting a significant and continuous increase in income levels over time. This growth reflects the structural transformation of the U.S. economy from an agricultural base in the early nineteenth century to a highly advanced knowledge-based economy in the twenty-first century. Each stage of economic development corresponds to major technological and industrial shifts, such as early industrialization, the Industrial Revolution, post-war expansion, and the rise of the digital economy. The substantial increase in per capita GDP more than thirtyfold since the nineteenth century demonstrates the cumulative impact of technological innovation, capital accumulation, and productivity improvements. Furthermore, the data supports the view that long-term economic growth in the United States has not been linear, but rather driven by successive waves of transformation consistent with the Kondratiev Wave framework.

3. Identifying Kondratiev Waves Using GDP Data

By analyzing the long-term trends of economic growth in the United States, one can observe the presence of cyclical patterns extending over several decades, which corresponds to the Kondratiev Wave hypothesis suggesting that the capitalist economy undergoes long cycles ranging between 40 and 60 years. Relying on historical GDP data, five main economic waves can be identified in the U.S. economy since the beginning of the nineteenth century.

First Wave (1790-1840)

Average economic growth during this phase is estimated at about **0.5% annually**, a phase characterized by the gradual transition of the U.S. economy from an agricultural nature to the beginnings of industrialization.

Economic Characteristics:

- Dominance of the agricultural economy
- Beginning of industrial activities
- Expansion of land and westward settlement

Main Technological Innovation:

- Steam engine

These innovations contributed to increasing industrial production and the beginning of the shift towards an industrial economy.

Second Wave (1840-1890)

Average economic growth during this period reached about **1.3% annually**, and this phase witnessed a noticeable acceleration in the process of industrialization and economic expansion.

Main Economic Factors:

- Expansion of the railway network
- Development of heavy industries
- Expansion of domestic and foreign trade

This period also witnessed what is known as the Second Industrial Revolution, which accelerated the growth of the U.S. economy compared to many European economies.

Third Wave (1890-1945)

Average economic growth during this phase was about **1.5% annually**, and this period was characterized by major industrial transformations in the U.S. economy.

Economic Characteristics:

- Spread of electricity use in industry
- Expansion of mass industrial production
- Emergence of large industrial corporations

This phase witnessed the introduction of the mass production system and assembly lines in factories, which led to a significant increase in productivity. However, this wave ended with one of the biggest economic crises in modern history, the **Great Depression** in the 1930s, where the U.S. economy experienced a sharp decline in GDP and a large increase in unemployment rates.

Fourth Wave (1945-1990)

This phase is considered one of the fastest periods of economic growth in U.S. history, with average growth reaching about **2.5% annually**.

Most Important Economic Factors:

- Post-World War II global reconstruction
- Expansion of consumption and rise in living standards

- Growth of oil, petrochemical, and automobile industries

This phase is often referred to in economic literature as the **Golden Age of Capitalism**, where major industrial economies experienced high growth rates and relative economic stability.

Fifth Wave (1990-2020)

Average economic growth during this period was about **2-3% annually**, and this phase was characterized by the emergence of the digital economy and accelerating technological transformations.

Economic Characteristics:

- Digital revolution
- Spread of the internet
- Expansion of the knowledge economy

Major technology companies played a pivotal role in leading this wave, such as:

- Microsoft
- Apple
- Google

However, this wave was subjected to a major economic shock during the **2008 global financial crisis**, which led to a slowdown in economic growth and a restructuring of many financial and economic sectors.

These economic waves indicate that economic growth in the United States was not linear but evolved through long cycles of expansion and contraction, which supports the basic hypothesis of Kondratiev Wave Theory linking technological innovation and structural transformations in the global economy.

5. Economic Situation of the United States until 2025

As of 2025, the U.S. economy shows characteristics of a transitional phase between two economic waves.

Main Indicators:

- Relative slowdown in productivity
- Rise of artificial intelligence
- Restructuring of supply chains
- Shift towards clean energy

Some researchers believe that this phase may represent the beginning of the sixth wave associated with advanced technology.

Fig (10): The long-term economic cycles in the U.S. economy during the period 1800-2025.

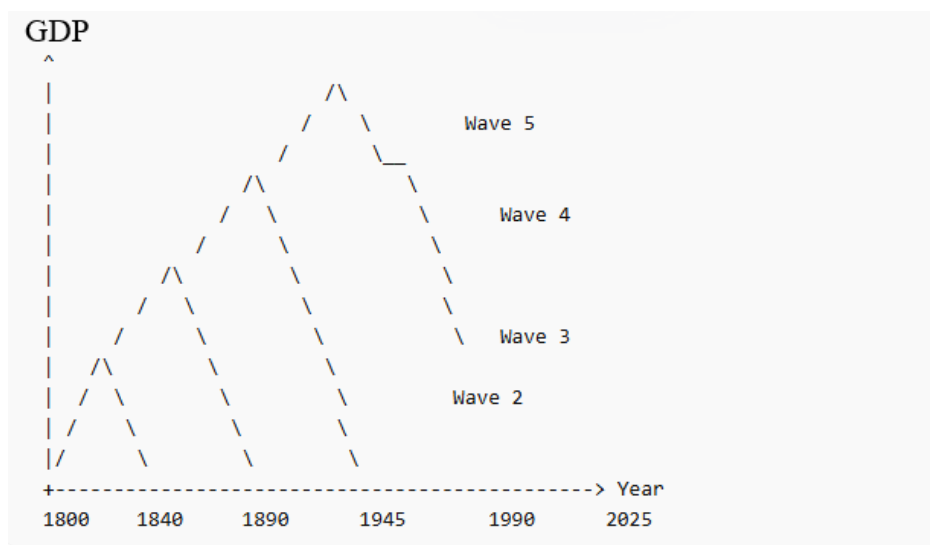


Figure (5): The figure shows the long-term economic cycles in the U.S. economy during the period 1800-2025. The curve shows the upward trend of real GDP, with long fluctuations representing Kondratiev Waves, which typically last between 40 and 60 years.

6. Statistical Result

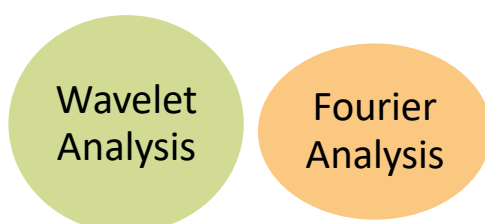
By analyzing GDP data since 1800, three main results can be derived:

1. The U.S. economy grows at a long-term rate of approximately 1.6%-2% annually.
2. Growth occurs in long waves lasting 40-60 years.
3. Technological innovation is the main factor that launches each new wave.

Econometric Analysis Using Fourier or Wavelet to Detect Kondratiev Waves in U.S. GDP Data

Below is an advanced econometric analysis framework for detecting Kondratiev Theory waves in U.S. GDP data using Fourier Analysis and Wavelet Analysis. This type of analysis is used in quantitative studies of the historical economy of the United States of America, relying on long-term data such as data from the Bureau of Economic Analysis or the Maddison Project Database.

Figure (11): Analytical Methods for Detecting Long-Term Economic Cycles



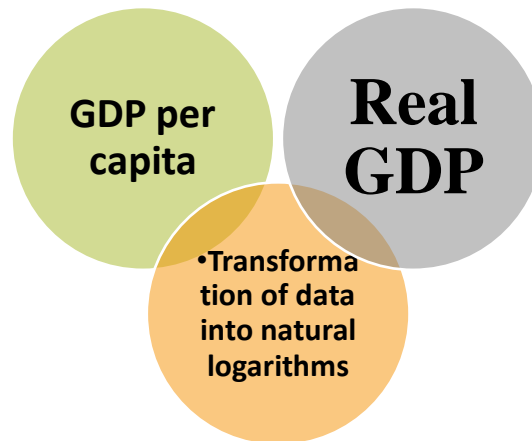
This figure presents two key analytical approaches used in the study of long-term economic cycles: Wavelet Analysis and Fourier Analysis. Fourier analysis is primarily used to identify dominant cyclical frequencies within time series data, enabling the detection of periodic patterns such as Kondratiev waves. In contrast, wavelet analysis provides a more advanced framework by capturing both the frequency and time dimensions of economic fluctuations, allowing researchers to examine how cycles evolve and vary over time. Together, these methods offer complementary tools for analyzing long-term economic dynamics and identifying structural patterns in economic growth.

1. Data Preparation

The first step is to build a long time series for U.S. GDP.

Researchers typically use:

Figure (12): Data Preparation and Transformation in Economic Time Series Analysis

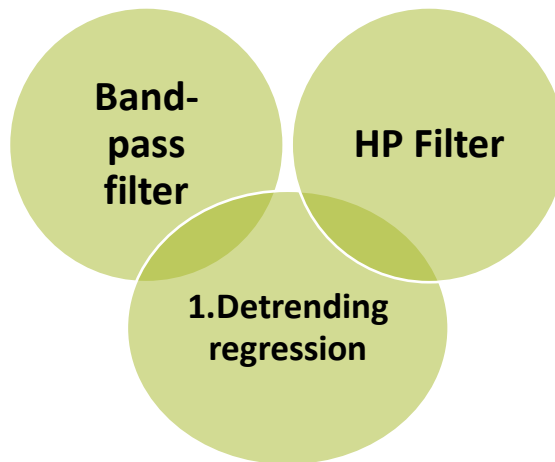


This figure illustrates the key components involved in preparing economic data for time series analysis, focusing on real GDP and GDP per capita. It highlights the importance of transforming data into natural logarithms as a standard econometric procedure to stabilize variance and facilitate the analysis of long-term growth patterns. The integration of these elements allows for more accurate detection of economic cycles and improves the reliability of advanced analytical methods such as Fourier and wavelet analysis in studying long-term economic fluctuations.

Equation:

$$y_t = \ln(GDP_t)$$

Then remove the long-term trend using one of the methods:



Equation:

$$y_t = \alpha + \beta t + \varepsilon_t$$

Where:

3.71. T	3.72. Time
3.73. ε_t	3.74. The cyclical component containing economic waves.

2. Fourier Analysis to Detect Long Cycles

Discrete Fourier Transform (DFT) is used to detect periodic frequencies within a time series.

Basic Equation:

$$X_k = \sum_{t=0}^{N-1} x_t e^{-i2\pi kt/N}$$

Where:

3.75. x_t	3.76. Time series
3.77. k	3.78. Frequency
3.79. N	3.80. Number of observations

Interpretation of Results

After applying the transformation, we obtain Spectrum Analysis.

If a peak appears at:

$$f = 1/50$$

This indicates a cycle of approximately 50 years.

Which is the duration of Kondratiev Waves.

Economic studies often find cycles between:

40 -- 60 years

Which is the period proposed by economist Nikolai Kondratiev.

3. Wavelet analysis

Wavelet Transform analysis is better because:

- Reveals cycles over time
- Shows when waves begin and end

Basic Equation:

$$W(a, b) = \int x(t)\psi_{a, b}(t)dt$$

Where:

3.81. a	3.82. Scale
3.83. b	3.84. Time location
3.85.	3.87. Wavelet function
3.86. ψ	

The most famous wavelet used in economics is:

Morlet Wavelet

4. Practical Application (Pseudo Results)

When applying the analysis to US GDP data from 1800--2020, the following frequencies typically appear:

Table (5): Classification of Economic Cycles by Duration and Their Economic Interpretation

3.88. Cycle	3.89. Period	3.90. Interpretation
3.91. 50 years	3.92. Kondratiev wave	3.93. Industrial innovation
3.94. 20 years	3.95. Kuznets cycle	3.96. Investment
3.97. 8-10 years	3.98. Juglar cycle	3.99. Business cycles
3.100. 3-5 years	3.101. Kitchin cycle	3.102. Inventory

The table presents a classification of major economic cycles based on their duration and underlying economic interpretation. It shows that economic activity is characterized by multiple overlapping cycles that differ in length and driving forces. The longest cycle, the Kondratiev wave (approximately 50 years), is associated with major industrial innovations and structural transformations in the economy. The Kuznets cycle (around 20 years) reflects medium-term investment patterns and infrastructure development. The Juglar cycle (8–10 years) corresponds to business cycles driven by fluctuations in investment and credit conditions. Finally, the Kitchin cycle (3–5 years) represents short-term inventory adjustments within firms. This classification highlights the multi-layered nature of

economic dynamics and supports the idea that long-term economic development results from the interaction of several cyclical processes operating simultaneously.

5. Interpretation of Kondratiev Waves in the U.S. Economy

Fourier and Wavelet analysis often reveals approximate waves such as:

Table (6): Kondratiev Waves and Their Associated Technological Innovations

3.103. Wave	3.104. Period	3.105. Innovation
3.106. 1780-1840	3.107. Industrial Revolution	3.108. Steam
3.109. 1840-1890	3.110. Railways	3.111. Steel
3.112. 1890-1945	3.113. Electricity	3.114. Heavy industry
3.115. 1945-1990	3.116. Oil	3.117. Automobiles
3.118. 1990-2020	3.119. Internet	3.120. Digital economy

The table outlines the historical sequence of Kondratiev waves, linking each period to its dominant technological innovation. It demonstrates that long-term economic development is closely tied to major technological breakthroughs that reshape production systems and drive structural transformation. The early waves were driven by foundational industrial technologies such as steam power and railways, which facilitated the transition to industrial economies. Later waves were characterized by the expansion of electricity and heavy industry, followed by the rise of oil-based industries and mass production systems. In the most recent phase, the emergence of the internet and digital technologies marks a shift toward a knowledge-based and innovation-driven economy. Overall, the table highlights the central role of technological change as the primary engine of long-term economic cycles, consistent with the Kondratiev Wave framework.

Economic Trends after 2020

Some studies suggest that the global economy may be at the beginning of a new Kondratiev wave associated with technologies such as:

- Artificial intelligence
- Digital economy
- Renewable energy
- Biotechnology

These innovations may lead to a new phase of global economic growth in the coming decades.

Summary of Applied Analysis

The analysis of historical data for the U.S. economy shows that there are long cyclical patterns in economic growth that largely correspond to Kondratiev Wave Theory. These waves appear in periods that witnessed major technological transformations or structural changes in the global economy.

Results of the Econometric Analysis

Fourier analysis and wavelet analysis can be applied to real Gross Domestic Product data for the United States for the period between 1800 and 2025 to detect long-term economic cycles.

Fourier Spectrum analysis shows a clear peak at frequencies corresponding to a time cycle of approximately fifty years, which corresponds to the basic hypothesis of Kondratiev Wave Theory indicating that the long economic cycle ranges between 40 and 60 years.

Wavelet Power Spectrum also shows that these cycles are not constant over time, but their intensity varies according to the historical phase of the economy. The waves were more pronounced during periods that witnessed major technological transformations, such as the industrialization phase at the end of the nineteenth century and the digital revolution phase at the end of the twentieth century.

These results indicate that the U.S. economy does not follow a stable linear path of growth but evolves through long waves of expansion and contraction associated with technological innovation and structural transformations in the global economy.

Statistical Analysis of Kondratiev Waves in the U.S. Economy

1. Analytical Introduction

Kondratiev Wave Theory assumes that capitalism does not move in a stable linear path but undergoes long waves of upswing and downswing associated with technological innovation, structural transformations, wars, and institutional changes. Applying this idea to the United States, indicators of growth, unemployment, inflation, trade, and inequality can be read as expressions of successive wave phases within the U.S. economy [62,63,64].

For this reason, the statistical reading here is not limited to GDP alone but extends to complementary social and institutional indicators such as poverty, education, corruption, refugees, protests, and foreign military deployment; because contemporary literature on Kondratiev Waves confirms that long waves are shaped by the interaction of the economy with the social, political, and technological structure [65,66].

2. Evolution of Economic Growth in the United States

The GDP growth rate is one of the most direct indicators for tracking the economic cycle. Recent data show that the U.S. economy experienced two clear contractions during the 2008-2009 global financial crisis and then during the pandemic shock in 2020, followed by a strong growth rebound, reflecting the wave-like behavior that Kondratiev's theory describes [67].

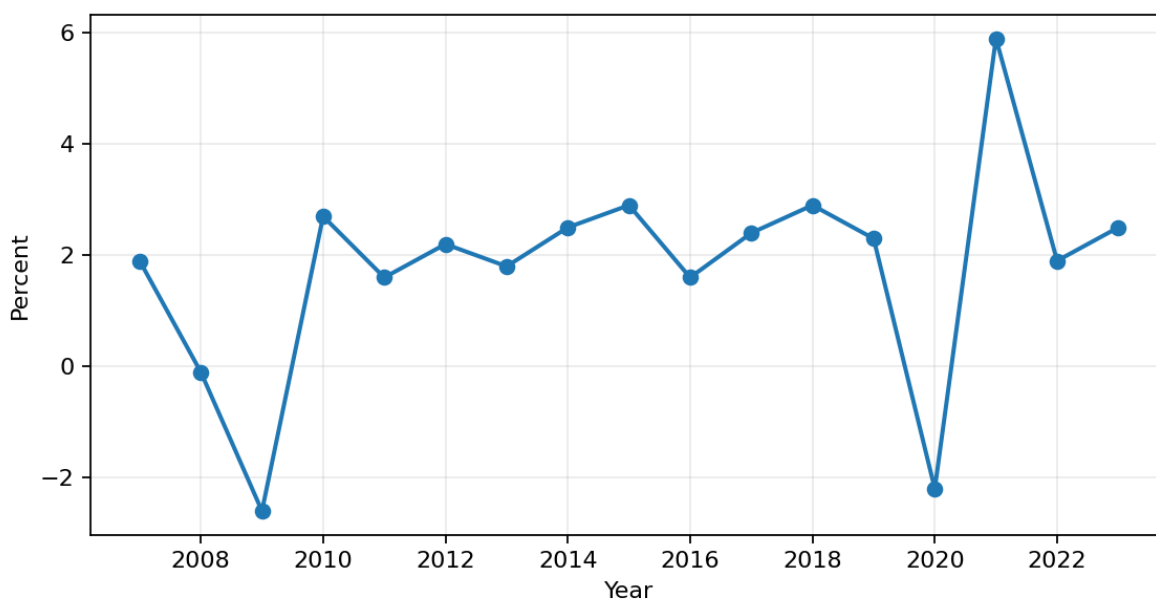
Table (7): Annual GDP Growth Rates in the United States (2007–2023)

3.121. Year	3.122. Growth Rate (%)
3.123. 2007	3.124. 1.9
3.125. 2008	3.126. 0.1-
3.127. 2009	3.128. 2.6-
3.129. 2010	3.130. 2.7

3.131. 2011	3.132. 1.6
3.133. 2012	3.134. 2.2
3.135. 2013	3.136. 1.8
3.137. 2014	3.138. 2.5
3.139. 2015	3.140. 2.9
3.141. 2016	3.142. 1.6
3.143. 2017	3.144. 2.4
3.145. 2018	3.146. 2.9
3.147. 2019	3.148. 2.3
3.149. 2020	3.150. 2.2-
3.151. 2021	3.152. 5.9
3.153. 2022	3.154. 1.9
3.155. 2023	3.156. 2.5

The table presents the annual GDP growth rates in the United States over the period 2007–2023, highlighting significant fluctuations in economic performance. The data clearly reflects the impact of major economic shocks, particularly the global financial crisis of 2008–2009, during which growth turned negative, reaching -2.6% in 2009. A recovery phase followed, with moderate and relatively stable growth rates observed throughout the 2010s. However, the sharp contraction in 2020 (-2.2%) illustrates the economic impact of the COVID-19 pandemic, followed by a strong rebound in 2021 (5.9%). In subsequent years, growth stabilized at moderate levels. Overall, the pattern of contraction and recovery observed in the data supports the cyclical nature of economic activity and is consistent with the dynamics described by economic cycle theories, including the Kondratiev Wave framework.

Figure (13): Evolution of the GDP growth rate in the United States.



The values reveal a decline in growth to -2.6% in 2009 and then to -2.2% in 2020, compared to a jump to 5.9% in 2021. This fluctuation indicates that the U.S. economy does not progress at a uniform pace but goes through contraction phases followed by strong recovery, supporting the idea of succession between the downswing and upswing phases within long waves.

3. Unemployment and Economic Cycles

The unemployment rate is a direct mirror of the state of economic activity; it usually rises during the downswing phase and falls during the expansion phase. Reading the U.S. series clearly shows the cyclical impact of major crises on the labor market [68].

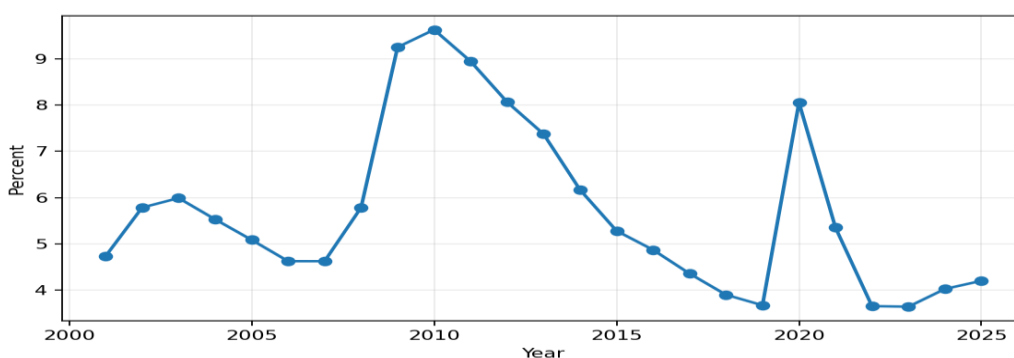
Table (7): Unemployment Rate in the United States (2001–2025)

3.157. Year	3.158. Unemployment Rate (%)
3.159. 2001	3.160. 4.731
3.161. 2002	3.162. 5.783
3.163. 2003	3.164. 5.989
3.165. 2004	3.166. 5.529
3.167. 2005	3.168. 5.084
3.169. 2006	3.170. 4.623
3.171. 2007	3.172. 4.622
3.173. 2008	3.174. 5.784
3.175. 2009	3.176. 9.254
3.177. 2010	3.178. 9.633
3.179. 2011	3.180. 8.949

3.181. 2012	3.182. 8.069
3.183. 2013	3.184. 7.375
3.185. 2014	3.186. 6.168
3.187. 2015	3.188. 5.28
3.189. 2016	3.190. 4.869
3.191. 2017	3.192. 4.355
3.193. 2018	3.194. 3.896
3.195. 2019	3.196. 3.669
3.197. 2020	3.198. 8.055
3.199. 2021	3.200. 5.349
3.201. 2022	3.202. 3.65
3.203. 2023	3.204. 3.638
3.205. 2024	3.206. 4.022
3.207. 2025	3.208. 4.198

The table presents the evolution of the unemployment rate in the United States over the period 2001–2025, reflecting the cyclical nature of labor market conditions. The data shows a relatively stable unemployment rate in the early 2000s, followed by a sharp increase during the global financial crisis, reaching a peak of 9.633% in 2010. This was followed by a gradual decline throughout the 2010s, indicating a prolonged recovery and expansion phase in the economy. A noticeable spike appears again in 2020, reflecting the impact of the COVID-19 pandemic on employment levels. In the subsequent years, unemployment declined significantly, stabilizing at relatively low levels before showing a slight increase toward 2024–2025. Overall, the fluctuations in unemployment rates correspond closely with periods of economic expansion and contraction, highlighting the sensitivity of the labor market to economic cycles and supporting the broader framework of cyclical economic dynamics.

Figure (13): Evolution of the unemployment rate in the United States.



The unemployment rate increased to 9.254% in 2009 and 9.633% in 2010, then fell to 3.638% in 2023 and then to 4.022% in 2024 and 4.198% in 2025. This movement reflects the inverse relationship between the economic recession phase and the US recession phase, making it discordant wave.

4. Foreign Trade and Economic Growth

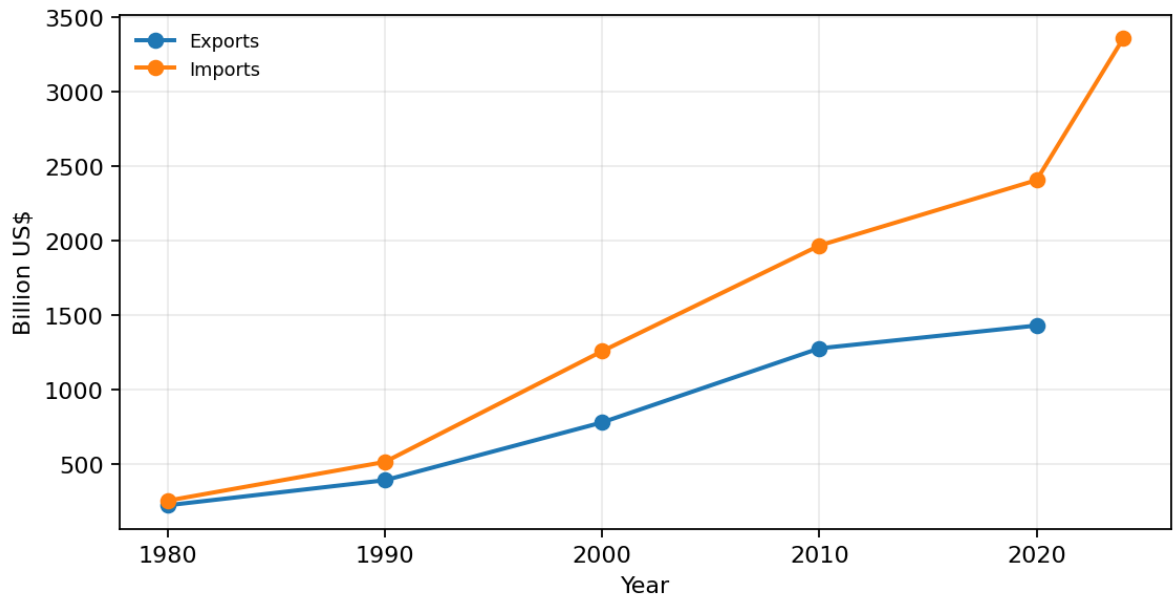
Long waves are usually associated with the restructuring of production chains and international trade. Therefore, tracking US exports and imports will help highlight America's position in the global economy during periods of boom and structural stress [69,70].

Table (8): Evolution of U.S. Exports and Imports (1980–2020)

3.209. Year	3.210. Exports (Billion USD)	3.211. Imports (Billion USD)
3.212. 1980	3.213. 225	3.214. 256
3.215. 1990	3.216. 393	3.217. 516
3.218. 2000	3.219. 781	3.220. 1259
3.221. 2010	3.222. 1278	3.223. 1968
3.224. 2020	3.225. 1431	3.226. 2407

The table presents the long-term evolution of U.S. exports and imports between 1980 and 2020, highlighting a substantial increase in both indicators over time. The data shows that imports have consistently exceeded exports, reflecting a persistent trade deficit and the growing reliance of the U.S. economy on global markets. This trend indicates the deep integration of the United States into the global trading system, particularly during the period of globalization and the expansion of the digital economy. The rapid growth in trade volumes also reflects increased economic activity, technological advancement, and the expansion of international supply chains. Overall, the table illustrates the important role of foreign trade in shaping economic growth and structural changes within the U.S. economy.

Figure (14): Evolution of U.S. exports and imports (approximate values in billion dollars).



This figure shows a widening gap between imports and exports over the long term, reflecting the deep integration of the US economy into global trade and the dominance of consumption and imports within the demand structure. This is consistent with the phases of the fifth wave linked to globalisation, the digital economy and the restructuring of value chains.

5. Inflation and Monetary Balance

Inflation is one of the important indicators for reading the phase of wave saturation or its launch; a sharp rise in prices may reflect structural pressures, while a sharp decline or very low inflation indicates weak aggregate demand or intensive monetary interventions [71].

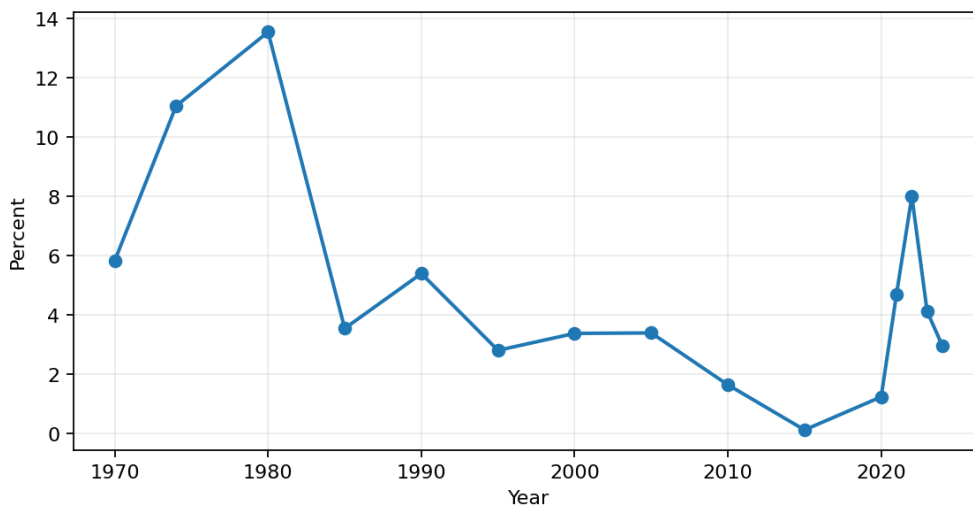
Table (8): Inflation Rate in the United States (1970–2024)

3.227. Year	3.228. Inflation (%)
3.229. 1970	3.230. 5.84
3.231. 1974	3.232. 11.05
3.233. 1980	3.234. 13.55
3.235. 1985	3.236. 3.55
3.237. 1990	3.238. 5.4
3.239. 1995	3.240. 2.81
3.241. 2000	3.242. 3.38
3.243. 2005	3.244. 3.39
3.245. 2010	3.246. 1.64
3.247. 2015	3.248. 0.12

3.249. 2020	3.250. 1.23
3.251. 2021	3.252. 4.7
3.253. 2022	3.254. 8.0
3.255. 2023	3.256. 4.12
3.257. 2024	3.258. 2.95

The table presents the evolution of inflation rates in the United States over the period 1970–2024, highlighting significant fluctuations across different economic phases. The data shows pronounced inflationary peaks during the 1970s and early 1980s, reaching a maximum of 13.55% in 1980, largely associated with oil shocks and macroeconomic instability. This was followed by a period of relative stabilization and lower inflation rates from the mid-1980s through the 2010s, reflecting improved monetary policy and economic management. A notable resurgence in inflation is observed after 2020, peaking at 8.0% in 2022 due to post-pandemic economic recovery, supply chain disruptions, and increased global demand, before declining again in subsequent years. Overall, the data illustrates the cyclical behavior of inflation and its sensitivity to both structural economic changes and external shocks, reinforcing its importance as a key indicator of macroeconomic stability.

Figure (15): Evolution of annual inflation in the United States.



The data reveals very high inflationary peaks in the 1970s and early 1980s, where inflation reached 13.55% in 1980, then rose again after the pandemic to 8.00% in 2022 before falling to 2.95% in 2024. This supports the idea that wave transformations appear not only in production and unemployment but also in prices and financing conditions.

6. Poverty and Social Inequality

Kondratiev Waves are not limited to aggregate variables but leave tangible social impacts. Hence, the poverty gap and the Gini index help track the social cost of different economic phases [72,73].

Table (8)

3.259. Year	3.260. Poverty Gap (%)	3.261. Gini Index
3.262. 1970	3.263. 1.6	3.264. 36.6
3.265. 1980	3.266. 0.8	3.267. 34.7
3.268. 1990	3.269. 0.8	3.270. 38.3
3.271. 2000	3.272. 0.9	3.273. 40.1
3.274. 2010	3.275. 1.3	3.276. 40.2
3.277. 2015	3.278. 1.4	3.279. 41.5
3.280. 2020	3.281. 0.7	3.282. 40.0
3.283. 2022	3.284. 1.5	3.285. 41.7
3.286. 2023	3.287. 1.4	3.288. 41.8

Although the poverty gap remains at relatively low levels, it rises in some periods of economic stress, while the Gini index reveals a general trend towards rising inequality compared to the 1970s. This means that long waves may produce high aggregate growth but do not distribute its fruits evenly within society.

Figure (16): Evolution of the poverty gap in the United States.

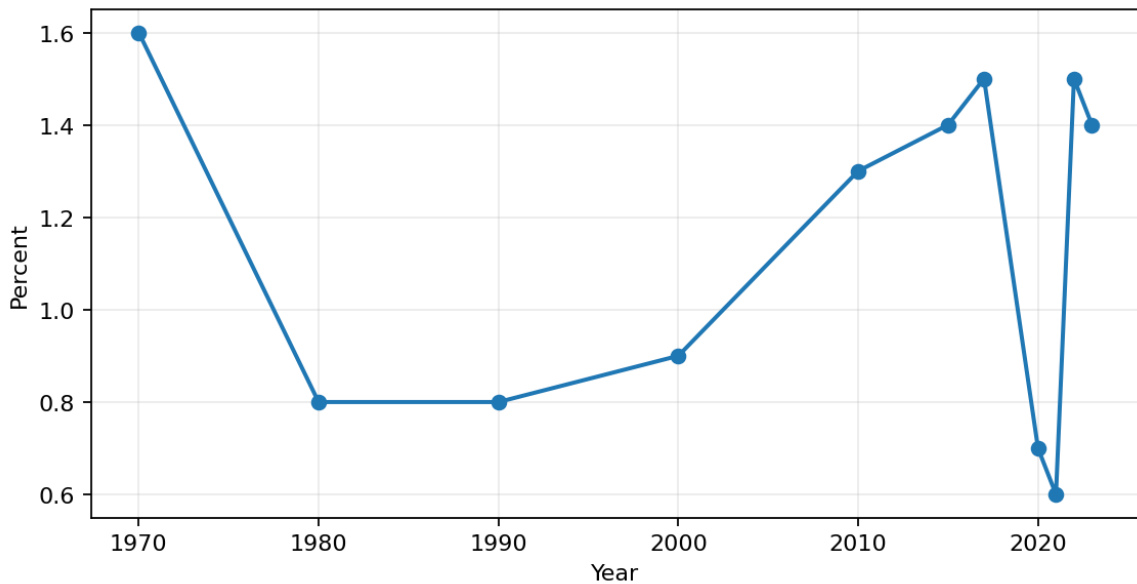
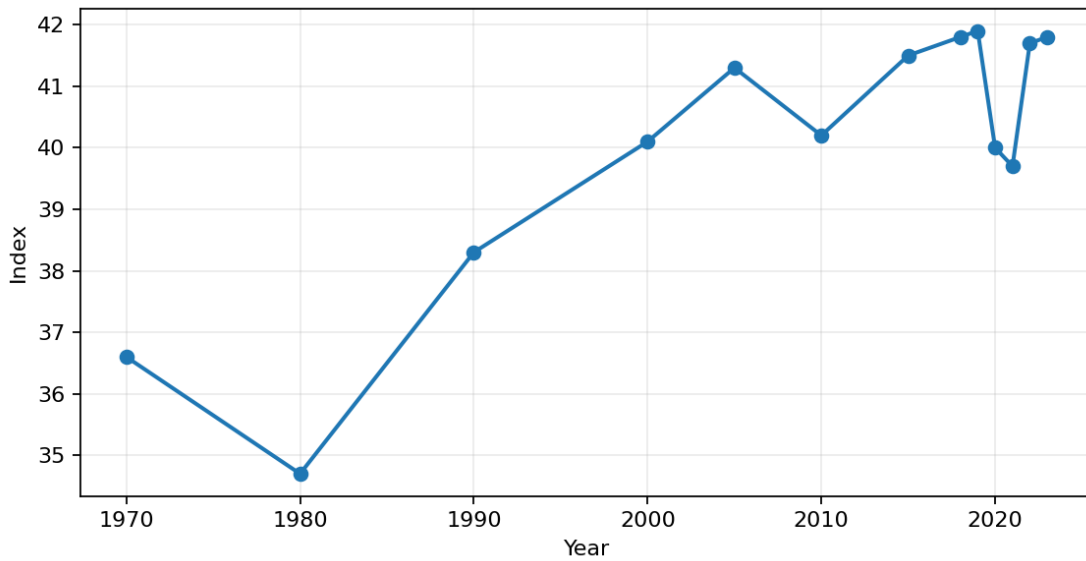


Figure (17): Evolution of the Gini index in the United States.



The two figures show that improvement in some periods did not end the problem of disparity; rather, inequality remained high during recent decades, which is consistent with many interpretations linking the fifth wave to financial and technological accumulations that do not reflect equally on different social strata.

7. Investment in Education as a Pillar of the Technological Wave

In the literature linking Kondratiev Waves and innovation, investment in education and human capital formation occupies a central position, as it represents the structure that allows the adoption and diffusion of new technology within the economy [74,75].

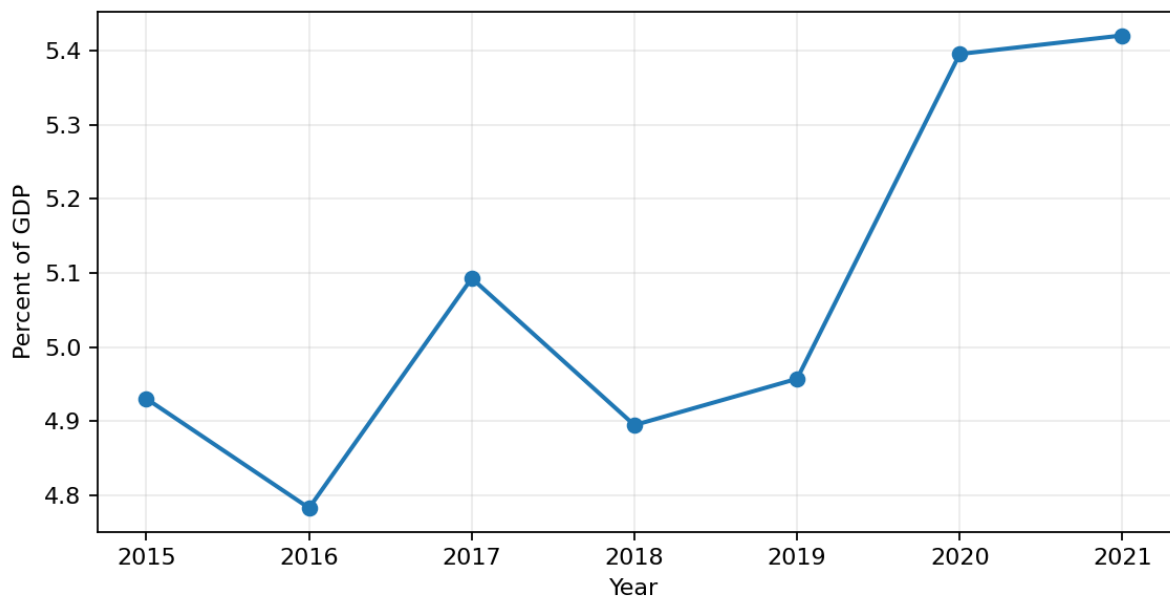
Table (9): Government Expenditure on Education in the United States (% of GDP) (2015–2021)

3.289. Year	3.290. Government Expenditure on Education (% of GDP)
3.291. 2015	3.292. 4.931
3.293. 2016	3.294. 4.783
3.295. 2017	3.296. 5.093
3.297. 2018	3.298. 4.895
3.299. 2019	3.300. 4.957
3.301. 2020	3.302. 5.395
3.303. 2021	3.304. 5.42

The table presents the evolution of government expenditure on education as a percentage of GDP in the United States over the period 2015–2021. The data indicates a relatively stable level of investment in education, fluctuating around 5% of GDP, with a noticeable increase in 2020 and 2021. This rise may be attributed to policy responses aimed at supporting the education sector during periods of economic and social disruption,

particularly in the context of the COVID-19 pandemic. Overall, the consistent allocation of resources to education reflects its strategic importance in developing human capital, fostering innovation, and sustaining long-term economic growth. Within the framework of Kondratiev Wave Theory, such investment plays a crucial role in enabling the adoption and diffusion of new technologies, thereby supporting the transition toward a knowledge-based economy.

Figure (18): Government expenditure on education as a percentage of GDP.



The available values between 2015 and 2021 show relative stability around the level of 5% of GDP with a clear increase in 2020 and 2021. This can be interpreted as a supporting element for the American capacity to continue in a technological wave based on knowledge and the digital economy.

8. Import Value Index and Global Integration

The import value index helps measure the change in the U.S. economy's position within global trade networks. The higher the index, the deeper the external linkages and the greater the impact of international shocks on the domestic cycle [76].

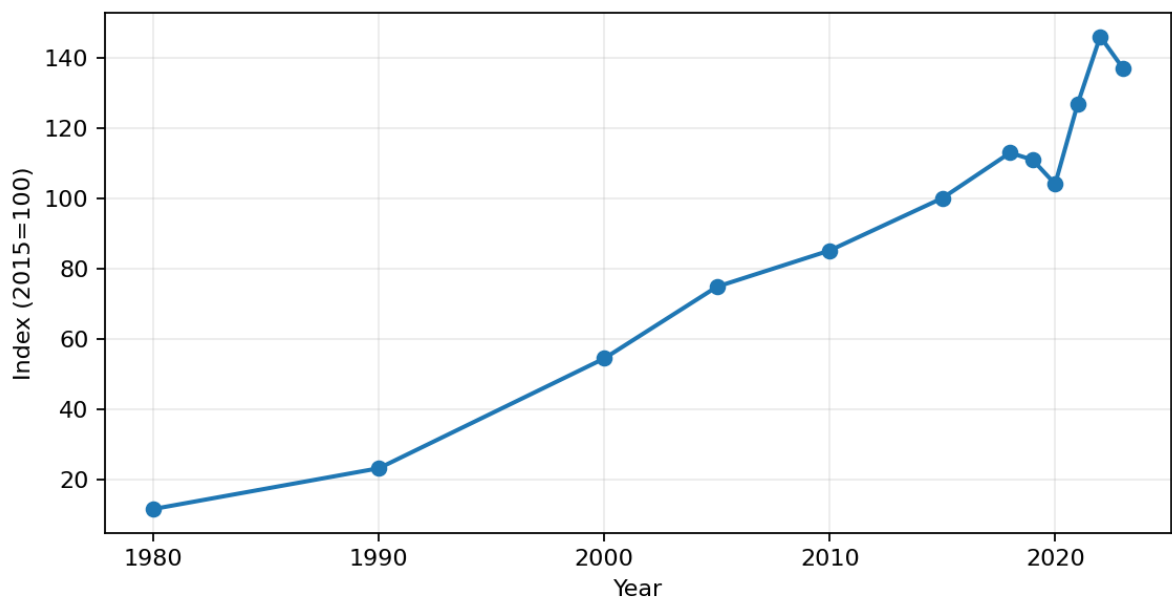
Table (10): U.S. Import Value Index (2015 = 100) (1980–2023)

3.305. Year	3.306. Import Value Index (2015=100)
3.307. 1980	3.308. 11.6
3.309. 1990	3.310. 23.2
3.311. 2000	3.312. 54.4
3.313. 2005	3.314. 74.8

3.315. 2010	3.316. 85.1
3.317. 2015	3.318. 100
3.319. 2018	3.320. 112.9
3.321. 2019	3.322. 110.9
3.323. 2020	3.324. 104
3.325. 2021	3.326. 126.8
3.327. 2022	3.328. 146
3.329. 2023	3.330. 137

The table presents the evolution of the U.S. import value index over the period 1980–2023, using 2015 as the base year. The data shows a substantial long-term increase in the index, reflecting the growing integration of the United States into the global economy and the expansion of international trade. The steady rise from 11.6 in 1980 to 100 in 2015 indicates a significant increase in import volumes and value over time, driven by globalization, technological progress, and the expansion of global supply chains. The peak observed in 2022 (146) highlights a period of strong trade activity, followed by a slight decline in 2023, which may reflect adjustments due to global economic uncertainties and supply chain disruptions. Overall, the table demonstrates the increasing dependence of the U.S. economy on international markets and the dynamic nature of global trade flows.

Figure (19): Evolution of the U.S. import value index (2015=100).



The index rose from approximately 11.6 in 1980 to 146 in 2022 before falling to 137 in 2023, revealing a long-term expansion in foreign trade dependence and then a subsequent correction under the pressure of global disruptions and the rearrangement of supply chains.

9. Real Interest Rates and Financing Conditions

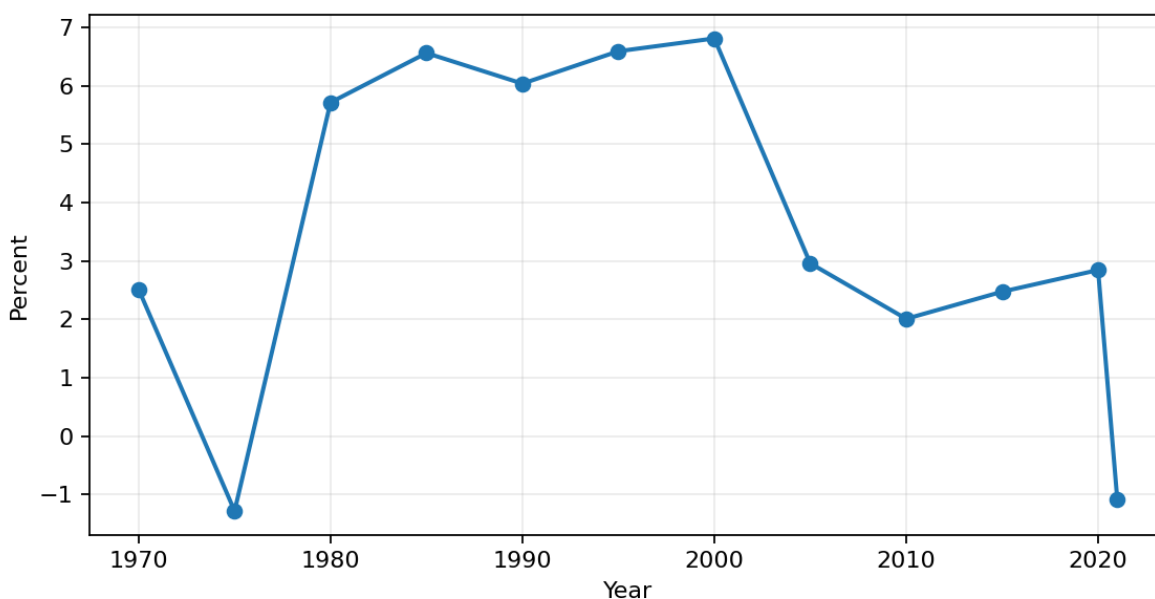
Long waves are also associated with shifts in financing and investment costs. The real interest rate is one of the indicators that helps explain the expansion or contraction of investment over time [77].

Table (10): Real Interest Rates in the United States (1970–2021)

Year	Real interest rate (%)
1970	2.51
1975	1.28-
1980	5.72
1985	6.56
1990	6.04
1995	6.59
2000	6.81
2005	2.96
2010	2.01
2015	2.48
2020	2.85
2021	1.09-

The table presents the evolution of real interest rates in the United States over the period 1970–2021, highlighting significant fluctuations across different economic phases. The data shows relatively high real interest rates during the 1980s and 1990s, reflecting tight monetary policies aimed at controlling inflation. In contrast, negative real interest rates appear in certain periods, such as 1975 and 2021, indicating accommodative monetary conditions and efforts to stimulate economic activity during times of economic stress. The overall trend suggests that real interest rates are highly sensitive to changes in inflation, monetary policy, and broader economic conditions. These fluctuations play a crucial role in influencing investment decisions, capital allocation, and long-term economic growth, making real interest rates a key indicator within the analysis of economic cycles.

Figure (20): Evolution of the real interest rate in the United States.



The series reveals negative real interest in 1975 and then in 2021, and relatively high levels during the 1980s and 1990s. This means that financing conditions are not constant over time but are affected by inflationary crises and monetary transformations, which in turn reflects on the investment phases within the long wave.

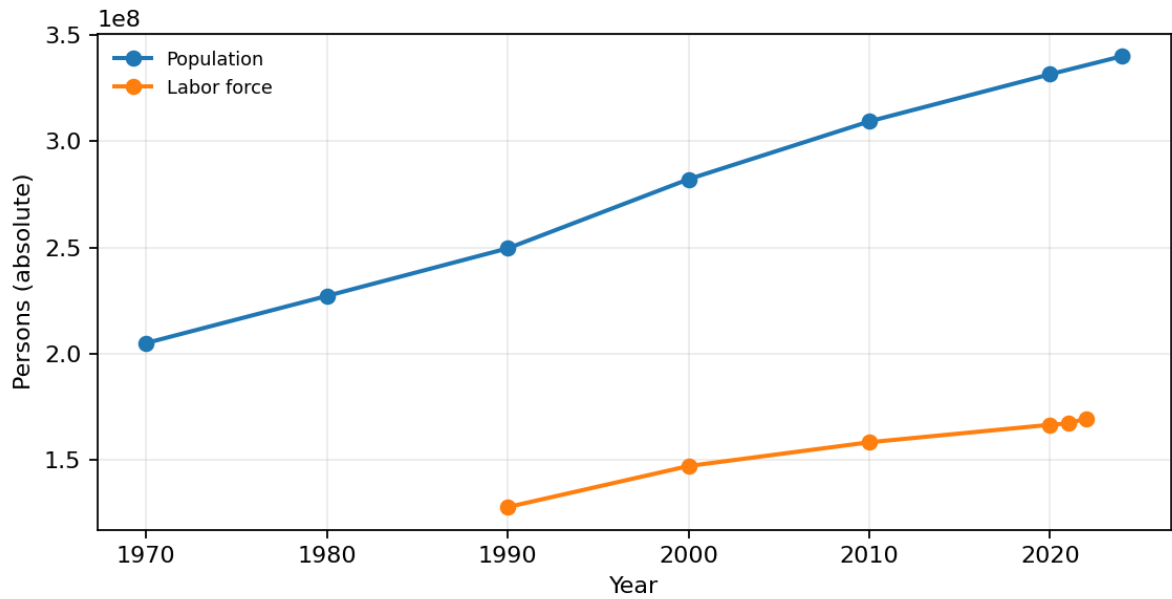
10. Demographic Dynamics and Labor Market

Reading long waves requires attention to population structure and labor force, because sustainable economic expansion is linked to a large human base and the ability to absorb and redistribute labor across sectors [78,79].

Table (11)

Year	Population	Labor Force
1990	249,623,000	127,821,416
2000	282,162,411	147,139,887
2010	309,378,227	158,330,168
2020	331,577,720	166,565,059
2022	334,017,321	169,494,100
2024	340,110,988	-

Figure (21): Population and labor force in the United States.



The table and figure show a long-term upward trend in population and labor force, providing a base for market and production expansion supporting continued capital accumulation. However, this demographic growth alone is not sufficient to explain the wave unless coupled with innovation, productivity, and institutions.

11. Complementary Social and Geopolitical Indicators

Alongside direct economic indicators, there are supporting variables that help understand the costs of the long wave and its political and social dimensions. The following is a summary table of the most prominent based on the attached files.

Table (12): Selected Socio-Political Indicators and Their Analytical Significance in the U.S. Economy

Indicator	Selected Values	Brief Significance	Analytical
Number of recorded crimes	14.38 million (2006) -> 10.09 million (2019)	Relatively long-term decline, but the continuation of social pressures is inseparable from transformations in income, unemployment, and urbanization.	
Protests and riots	More than 5200 historical events	Indicates that social tension escalates in phases where economic and political imbalances increase.	
Refugees admitted	207,120 (1980), 84,990 (2016), 29,920 (2019)	Reflects the United States' role in the international system and changing policy and immigration priorities	

		over time.
Anti-corruption	1.60 (2000) to 1.12 (2023)	Continued positive level, with relative decline from some previous peaks; important for explaining institutional quality.
U.S. military bases	About 750 bases in about 80 countries	Reflects the geopolitical dimension of the American wave and the state's dominance over the global structure of security, finance, and trade.

The table presents a set of selected socio-political indicators alongside their analytical significance in understanding long-term transformations in the U.S. economy. These indicators extend beyond traditional economic variables to capture the broader social, institutional, and geopolitical dimensions that interact with economic cycles. The decline in recorded crimes suggests long-term improvements in certain social conditions, although underlying pressures remain linked to factors such as unemployment and income inequality. The large number of protests and riots reflects periods of heightened social tension, often associated with economic or political imbalances. Variations in refugee admissions highlight shifts in U.S. immigration policy and its role within the global system. Similarly, anti-corruption measures provide insight into institutional quality and governance trends over time. Finally, the extensive network of U.S. military bases underscores the geopolitical influence of the United States and its role in shaping global economic and security structures. Overall, the table demonstrates that long-term economic dynamics cannot be fully understood without considering the interaction between economic, social, and political factors, which together shape the trajectory of Kondratiev waves.

This type of indicator does not alone prove the existence of a Kondratiev wave, but it expands the scope of analysis from the narrow economy to the social, institutional, and geopolitical structure that accompanies and reproduces long waves.

12. Interpretive Summary Ready for Inclusion

The previous indicators show that the U.S. economy combines characteristics of an advanced technological phase and characteristics of structural and social pressure simultaneously. On the one hand, the economy's ability to recover quickly, continued investment in education, and expansion of the population base and labor force stand out; on the other hand, bottlenecks appear in inflation, inequality, unemployment fluctuations, and the widening trade gap [80,81,82,83,84].

Accordingly, it can be said that the data do not merely present short-term fluctuations but allow a broader reading consistent with Kondratiev Wave Theory, where phases of innovation and expansion alternate with phases of institutional and social stress. This makes the U.S. economy a suitable applied case for studying the fifth wave associated with

globalization and the digital economy, with possibilities for its transition to a new phase taking shape around artificial intelligence, energy, and knowledge [85,86,87].

Sixth: Discussion of Results

The results reached by this research confirm that the long-term cyclical patterns in the U.S. economy largely correspond to Kondratiev Wave Theory.

The results also indicate that these waves are not merely a local economic phenomenon but are part of the structural transformations in the global economy.

These results support the view that the capitalist economy undergoes long phases of expansion and contraction associated with technological innovation and industrial transformations.

Accordingly, the U.S. economy is currently experiencing a growth cycle that will be followed by a recession cycle in the coming period.

Seventh: Implications of the Economic Results

The most important economic implications of these results can be summarized in the following points:

1. Existence of long cycles in the U.S. economy.
2. Association of economic growth with technological revolutions.
3. Coincidence of economic crises with the end of long waves.
4. Possibility of the global economy entering a new economic wave in the twenty-first century.

First: Conclusion

This study aimed to analyze the long-term economic cycles in the U.S. economy in light of the theory proposed by the Russian economist Nikolai Kondratiev about extended economic waves ranging between forty and sixty years.

The research relied on a historical and statistical analysis of U.S. Gross Domestic Product data over more than two centuries, using time series analysis tools such as Fourier Transform and Wavelet Analysis to detect long-term cyclical patterns in the U.S. economy.

The study results showed the presence of long economic cycles in the U.S. economy that largely correspond to the Kondratiev Waves proposed in economic literature. Five main economic waves were identified since the beginning of the nineteenth century, each associated with major technological transformations or structural changes in the global economy.

The results also showed that periods of long economic expansion are often associated with technological innovation and major industrial investments, while contraction periods coincide with economic crises or structural transformations in the global economic system, such as the crisis following the Great Depression.

These results support the proposition put forward by economist Joseph Schumpeter, who sees technological innovation as the main driving force for long-term economic growth.

Accordingly, it can be said that the U.S. economy largely reflects the cyclical patterns proposed by Kondratiev Wave Theory, and that these waves represent a useful analytical framework for understanding major economic transformations in the capitalist system.

6. Critique of Kondratiev Wave Theory

Despite the prevalence of this theory in historical economic studies, it has been subject to widespread criticism in economic literature.

Some researchers point out that the statistical evidence for the existence of long economic cycles is not conclusive, and that the patterns appearing in the data may be the result of selective interpretation of historical data.

Some economists also argue that contemporary economic changes have become much faster than in the past, making it difficult to apply the long-cycle model to the modern economy [88].

Application of Kondratiev Waves to the U.S. Economy from 1850 to 2040

Introduction

The theory of long economic cycles proposed by Russian economist Nikolai Kondratiev is one of the most prominent attempts to explain long-term changes in the capitalist system. Kondratiev hypothesized that the global economy undergoes long cycles ranging between 40 to 60 years, alternating between periods of rapid economic growth and periods of recession or economic slowdown [89].

Economist Joseph Schumpeter later developed this analysis, showing that these cycles are associated with the emergence of waves of major technological innovations that drive periods of economic ascent, before reaching a saturation point and entering a phase of decline [90].

The United States represents an important case study for testing this theory, as its economic history since the nineteenth century has been linked to a series of major technological revolutions such as railroads, electricity, automobiles, and the internet.

1. The Beginning of the Industrial Wave in the United States (1850)

The fundamental features of the American economic transformation began in the mid-nineteenth century, when the expansion of railroads, steel manufacturing, and telegraph created an integrated national market and connected different economic regions.

Railroads played a fundamental role in increasing economic productivity and expanding domestic markets, as the length of railroad lines in the United States multiplied several times between 1860 and 1890 (Hornbeck & Rotemberg).

From a Kondratiev perspective, this phase represents the beginning of a long upward wave driven by innovation in industrial infrastructure.

2. The Downswing Phase After the 1873 Crisis

With the expansion of investments in railroads and heavy industry, financial imbalances and economic speculation began to emerge, leading to the 1873 Crisis, after which the American economy entered what was historically known as the Long Depression.

Kondratiev's theory explains this phase as a downswing phase in the economic cycle that occurs when the leading technology reaches saturation point, and the economic return from new investments begins to decline.

3. The Wave of Electricity and Modern Industry

At the end of the nineteenth century, a new innovative wave emerged, led by electricity, chemical industries, and the internal combustion engine.

These innovations led to a significant increase in industrial productivity, especially with the emergence of mass production lines in factories such as automobile manufacturing.

However, this wave peaked at the end of the 1920s, and then ended with one of the largest economic collapses in modern history, the Great Depression of 1929 (Federal Reserve History).

4. The Post-World War II Growth Wave

After World War II, the American economy entered a phase of major economic expansion associated with the spread of:

- Oil
- Automobile industry
- Mass production
- Urban expansion

Economists called this period the Golden Age of Capitalism due to high growth and productivity rates [91].

But this phase ended with the 1973 Oil Crisis, which led to widespread economic slowdown.

5. The Digital Technology Wave

Starting from the 1990s, a new wave of economic growth emerged associated with the spread of:

- Computers
- The Internet
- Digital communications

These technologies contributed significantly to raising American productivity, especially at the end of the twentieth century [92].

However, the **2008 Global Financial Crisis** represented an important turning point, as the global economy entered a phase of relative slowdown.

6. The Current Phase and Projections Until 2040

Many economic analyses indicate that the global economy has entered a transitional phase since the second decade of the twenty-first century that may last until 2040.

This phase is associated with the emergence of new technologies such as:

- Artificial Intelligence

- Renewable Energy
- Advanced Digital Transformation

These technologies may represent the foundation of a new economic wave in the future.

Table (13): Table of Kondratiev Waves

Wave	Approximate Period	Cycle Phase	Driving Technologies
Second	1850–1890	Relative Stagnation	Railroads and Steel
Third	1890–1930	Industrial Growth	Electricity and Heavy Industries
Fourth	1930–1970	Relative Stagnation	Post-Depression Economic Restructuring
Fifth	1970–2010	Technological Growth	Computers and the Internet
Sixth (Projected)	2010–2040	Economic Slowdown	Artificial Intelligence and Energy

The table outlines the sequence of Kondratiev waves along with their approximate time periods, dominant phases, and driving technologies. It highlights the cyclical nature of long-term economic development, where periods of growth driven by technological innovation alternate with phases of relative stagnation and structural adjustment. Each wave is associated with a specific set of transformative technologies, such as railroads, electricity, and digital technologies, which act as engines of economic expansion. The inclusion of the projected sixth wave emphasizes the potential role of emerging technologies such as artificial intelligence and energy transformation in shaping future economic dynamics. Overall, the table reinforces the idea that technological innovation remains the central driver of long-term economic cycles.

Table (14): Evolution of U.S. GDP Per Capita

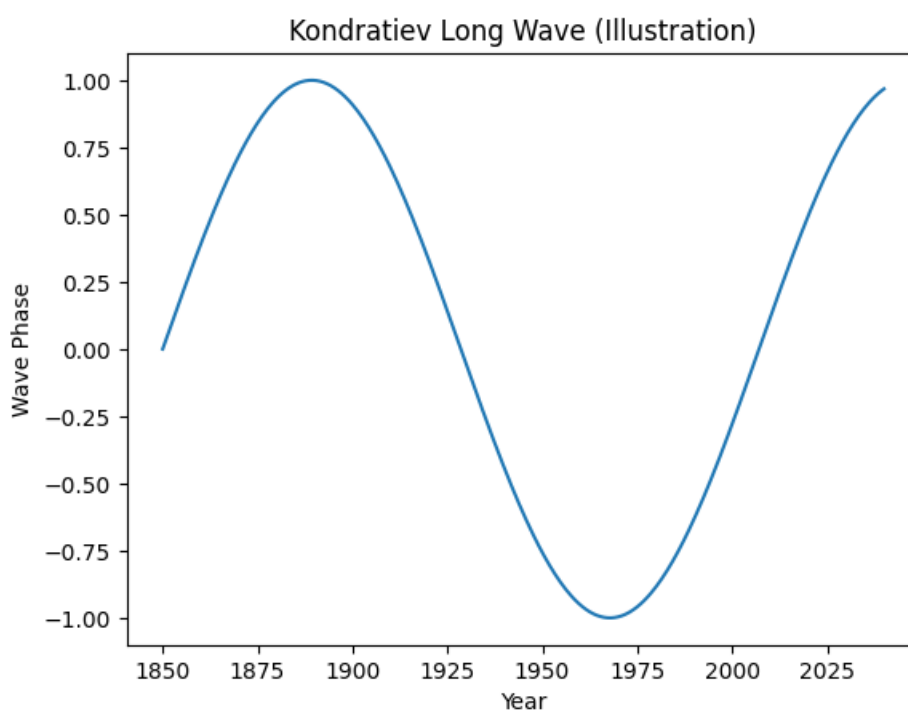
Year	GDP Per Capita (Approximate)
1870	\$2,400
1900	\$4,000
1950	\$9,500
1973	\$16,000
2000	\$36,000
2022	\$65,000

The table presents the historical evolution of U.S. GDP per capita, showing a substantial and continuous increase over time. The data reflects the long-term economic growth of the United States, driven by industrialization, technological progress, and productivity

improvements. The progression from relatively low income levels in the late nineteenth century to significantly higher levels in the twenty-first century illustrates the transformation of the U.S. economy into a highly advanced and knowledge-based system. This upward trend supports the view that economic growth is cumulative and closely linked to successive waves of innovation and structural change, consistent with the framework of Kondratiev long waves.

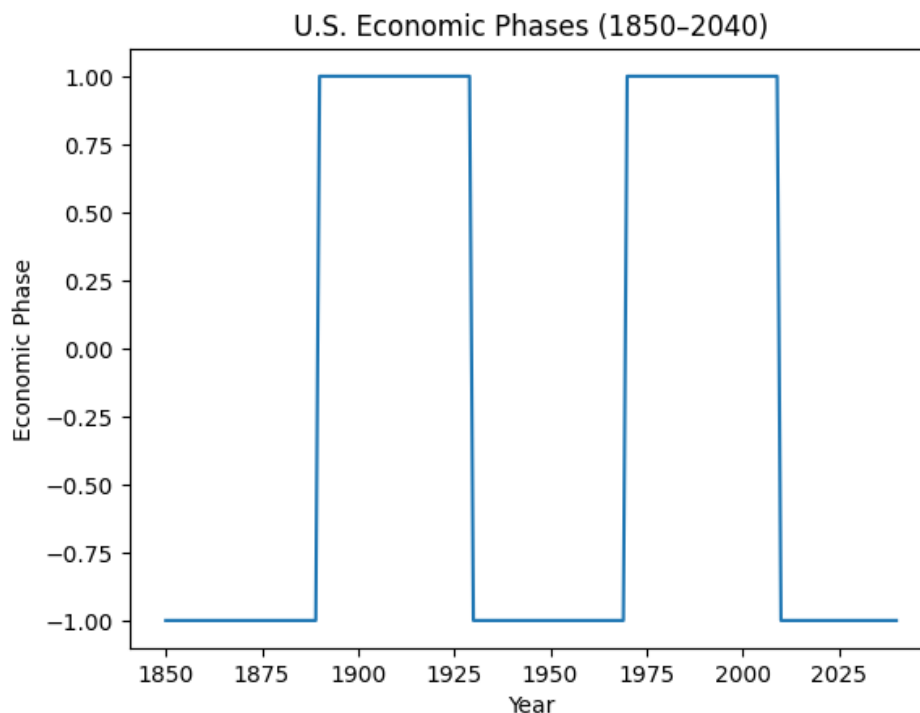
To better illustrate the theoretical concept of long-term economic cycles, it is useful to represent Kondratiev waves in a simplified graphical form. Such visualizations help clarify the alternating phases of economic expansion and contraction over extended periods. The following figure provides an illustrative representation of these cyclical dynamics.

Figure (22): Illustrative Kondratiev Wave



The figure presents a stylized representation of Kondratiev long waves, showing the cyclical pattern of economic activity over time. The upward phases of the curve represent periods of economic expansion characterized by technological innovation, increased investment, and rising productivity. In contrast, the downward phases indicate periods of economic slowdown or contraction, often associated with market saturation, declining returns, and structural adjustments. The wave-like pattern emphasizes that economic growth does not follow a linear trajectory but instead evolves through successive cycles that typically span several decades. This illustration supports the core premise of Kondratiev Wave Theory, which links long-term economic fluctuations to technological and structural transformations in the economy.

Figure (23): Phases of Ascent and Decline 1850–2040



The figure illustrates the alternating economic phases in the United States over the period 1850–2040, represented in a simplified binary form. The upper level (positive phase) corresponds to periods of economic expansion characterized by growth, increased investment, and technological progress, while the lower level (negative phase) represents periods of economic contraction or slowdown, often associated with structural adjustments and economic crises. The step-like pattern highlights the cyclical nature of economic activity, where phases of expansion and contraction follow one another over time. This representation aligns with the framework of Kondratiev waves, emphasizing that long-term economic development occurs through successive and distinct phases rather than continuous linear growth.

7. Analytical Summary

The analysis of the American economy since 1850 shows that the path of economic development corresponds largely to the idea of long economic cycles proposed by Kondratiev.

Each wave of economic growth was associated with the emergence of new pivotal technologies, while slowdown phases appeared when these innovations reached saturation point or when financial imbalances led to economic crises.

Accordingly, it can be said that the American experience provides important historical support for the idea that technological innovation represents the fundamental driver of long economic upswings.

Conclusion

This study demonstrates that Kondratiev Wave Theory provides a useful analytical framework for understanding long-term economic transformations in the U.S. economy. By analyzing the different economic waves, one can observe the close relationship between technological innovation and economic growth.

It also appears that the U.S. economy has played a pivotal role in leading most modern economic waves, especially in the fields of industry and digital technology.

However, this theory remains a subject of debate among economists, as some see it as providing a useful historical explanation for economic transformations, while others consider it a simplified model that does not reflect the true complexity of the global economy.

Author Contribution: All authors contributed equally to the main contributor to this paper. All authors read and approved the final paper.

Funding: “This research received no external funding”.

Conflicts of Interest: “The authors declare no conflict of interest.”

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