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Research Article

Using the Samuelson Model to Assess the French Economy's Business Cycle: A Mathematical Study

Syif Ali Abd Al-Rzaq[1] and Abdulhussein Jalil Abdulhasan[2*]

[1,2]Department of Economics, Faculty of Administration and Economics, University of Kufa, Iraq.

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ABSTRACT: The business cycle is considered one of the essential and replenishable topics. It represents one of the flaws of the capitalist economic system and several adjectives that give it this importance. Therefore, economists gave it the necessary attention. Perhaps the most well-known of them is Samuelson, credited with being one of the first economists to study and model the market cycle. It attempted to quantify and forecast the market cycle by integrating two concepts: the multiplier and the compressor. The tools of this model were applied in our research on the French economy over the period (1985-2018). The study could determine the business cycles that it has gone through in a precise and objective way, totaling five business cycles (for the studied period), including the start and end dates (except the last cycle, which has not ended yet).

Keywords: The Business Cycle, The Multiplier, The Accelerator, The Marginal Propensity to Consume, The Economic Crisis

* Corresponding Author, E-mail: abdulh.jalil@uokufa.edu.iq

1. Introduction

Perhaps the characteristics of the general business cycle (periodically, non-standard, not subject to a law, etc.) made the process of measuring it and predicting when it would happen difficultly. But this did not stop economists from developing mathematical models that estimate the business cycles, classify them according to their types, and try to predict them before their occurrence[1, 2]. In addition to its comprehensiveness, most economists gained significant importance and attention, most notably Harrod, Hanson, Godwin, Samuelson, and Kaldor [3]. They adopted the Multiplier-Accelerator model to measure and predict the business cycle. But they differed among themselves in the method used in designing the model. Some of them used the linear approach (the one which Samuelson used), while others used the non-linear method (such as Kaldor). Both the multiplier and the accelerator are two ideas independent of each other, as the multiplier idea belongs to the economist Keynes who adopted it to explain the state of equilibrium and its imbalance. But the method he adopted for the interpretation was static, in which he neglected the time factor, which led many economists to criticize it widely. But it did not become extinct due to the efforts of the new Pioneers of the Keynesian School, who revived it through the dynamics of the time factor generated by the income cycle with three levels of slowdown. The first was called the economic slowdown in spending, which Dennis Robertson introduced, the second was the period of slowing production that the Swedish economist Erik Lundberg brought. The third period was the period of slow receipt. The new Keynesians paid attention to the fact that the idea of the dynamic multiplier is unable to explain the feedback mechanism operating in the economy. Unless combining it with the idea of the accelerator that initially belonged to the French economist Albert Aftalion and later was developed by the American economist Clark [4, 5]. The concept of combining the effects of the multiplier and the accelerator has become one of the most critical economic models for studying the business cycle. The main problem is represented by the eternal flaws that the capitalist financial system suffers from, characterized by the economic fluctuations expressed in the business cycle[6]. To review Samuelson's model to get acquainted with it theoretically and know the unique mathematical mechanism of his work that clarifies the interaction between the multiplier and the accelerator and its application by measuring the French economy's business cycle. The mathematical tool that Samuelson used in his model to estimate the economic fluctuations (between the expansion at one time and the recession at other times) that the French capitalist economy suffers. The research has been divided into three sections; the first section reviews the historical roots of the multiplier-accelerator model. The second section deals with the mathematical mechanism through which the multiplier-the accelerator interacts, according to Samuelson. The third section deals with the process of economic measurement of the business cycle.

2. Samuelson's model

Perhaps the contributions and developments that the Keynesian model witnessed later opened the space for the Samuelson model (multiplier – accelerator model) to study the business cycles to be one of the first attempts to connect the multiplier and the accelerator [7-9]. Samuelson's model relied on the Keynesian equilibrium model,

the consumption equation presented by the economist Dennis Robertson to obtain the multiplier, and the restrictive accelerator model of investment developed by Clark. In addition to that, Samuelson relied on several assumptions to explain his model [10], as follows:

A. The prevailing state of the economy is the stagnation of business transactions within the economy.

B. The government does not interfere in economic activity, In the sense of the neutrality of fiscal policy. Meaning that the government spending is given and equal to (G0).

C. The absence of automatic investment and the induced investment result from changes in consumption due to changes in the national income in the previous period (the existence of a slow production period). The difference in the aggregate demand stimulates the productive enterprises to adjust their production capacity in the subsequent period.

D. The existence of a slow consumption period and independent consumption does not affect the equilibrium income.

Samuelson used the mathematical equations to explain his model and its derivation [11], as follows:

$$Y_t = C_t + I_t + G_t \dots\dots\dots\dots (1)$$
$$C_t = \beta Y_{t-1} \dots\dots\dots\dots\dots\dots\dots (2)$$
$$I_t = ă(C_t - C_{t-1}) \dots\dots\dots\dots (3)$$
$$I_t = ă(\beta Y_{t-1} - \beta Y_{t-2}) \dots\dots (4)$$
$$I_t = ă\beta Y_{t-1} - ă\beta Y_{t-2} \dots\dots\dots (5)$$
$$Y_t = \beta Y_{t-1} + ă\beta Y_{t-1} - ă\beta Y_{t-2} + G_0 \dots\dots\dots (6)$$
$$Y_t - \beta(1 + ă)Y_{t-1} + ă\beta Y_{t-2} = G_0 \dots\dots\dots (7)$$

Where (Y_t) represents the national income at period (t), (C_t) is the family consumption at period (t), (I_t) is the capital accumulation (induced investment), (Y_{t-1}) and (Y_{t-2}) represent the slowing national income for one and two periods respectively, (C_{t-1})and (I_{t-1}) are both the slowing consumption and slowing investment for one period of time, (β) represents the marginal propensity to consume, and (ă) is the accelerator.

During the state of equilibrium, the national income is constant over time, i.e. ($Y_t = Y_{t-1} = Y_{t-2}$). At this point, the effect of the accelerator fades away, and the Samuelson model becomes an analog of the Keynesian model [12], no more, which shows the impact of the multiplier only and thus forms the following:

$$Y^* = \frac{1}{1-\beta} G_0 \dots\dots\dots\dots (8)$$

According to Samuelson (20), an equation of the second-degree difference refers to the equilibrium level of income. It is a developed version of Keynes's equation for the equilibrium income. Also, it shows that the equilibrium income (Y_t) is mainly determined by relying on the values of the marginal propensity to consume (β) that determines the value of the multiplier, and by depending on the capital-to-output ratio (ă), which expresses the value of the accelerator [(1)]. The speed at which the income changes as a result of the interaction of the multiplier and the accelerator depends inversely on the value of the marginal propensity to save (MPS) ($1 - \beta$) and directly on the value of the accelerator. The lower value of (MPS) and the higher value of the accelerator, the faster the capital doubling, which leads to the doubling of income. Therefore, Samuelson intended to use the homogeneous difference equation ($Y_t = u_t + Y^*$) to explain the deviations of the national income from the equilibrium level over time [13], and as follows:

a. Replacing equation (20) with the homogeneous difference equation or deviation from the following income equilibrium level:

$$u_t - \beta(1 + ă)u_{t-1} + \beta ă u_{t-2} = 0 \dots\dots\dots\dots (9)$$

b. Solve the previous Differences equation by using its Characteristic Equation•, and as follows

$$x^2 - \beta(1 + ă)x + \beta ă = 0 \dots\dots\dots\dots (10)$$

c. The Characteristic Equation (10) can be solved using the following Quadratic Formula:

$$x_{1,2} = \frac{\beta(1 + ă) \pm \sqrt{\left(\beta(1 + ă)\right)^2 - 4\beta ă}}{2} \dots\dots\dots\dots (11)$$

Where ($x_{1,2}$) is the root of the characteristic equation depends entirely on the value of the multiplier and the accelerator. The mathematical sign (±) indicates that the equation has two solutions, and both of them depend on the root value, which can be one of three cases. If the matter under the radical is zero, then the equation has a single real solution which is ($x_1 = x_2 = \frac{\beta(1+ă)}{2}$). But if the value is negative, then the equation does not have a

- characteristic equation: It is one of the methods of solving differential or exponential equations of the second degree and more with one variable, and it is called the distinction as it distinguishes between the multi-rooted equation and the one root

real solution. In this case, trigonometric functions are used to solve it because it has two complex solutions [14]. If the value is positive, then it has two real solutions:

$(x_1 = \frac{\beta(1+ă)-\sqrt{\Delta}}{2})$ and $(x_2 = \frac{\beta(1+ă)+\sqrt{\Delta}}{2})$.

Therefore, Samuelson developed a hypothetical set of values for both the marginal propensity to consume and the accelerator coefficient to explain the situations in which economic activity may pass and describe them according to the logic of the business cycle. He explained that the initial changes that the investment witnesses often generate a continuous increase in the national income [10, 15, 16], and the summary of these cases is :

Table (1). The effect of the multiplier and the accelerator interaction on the deviation of the national income from the equilibrium level

Case	(Real Roots) $(\beta(1+ă)^2 \geq 4ă)$ *	(Complex Roots) $(\beta(1+ă)^2 < 4ă)$
1	(Monotonic Damping) $(ă \leq \beta)$	(Explosive Oscillation) $(\frac{1}{\beta} < ă)$
2	There is no deviation from the equilibrium level, and the state of the economy is stable (stationary) $(ă = 1)$and $(\beta = 1)$	(Harmonic Oscillations) $(\frac{1}{\beta} = ă)$
3	(Monotonic Explosion) $(ă > \beta)$	(Damped Oscillation) $(\frac{1}{\beta} > ă)$

Source: Prof. Dr. Gunter Gabisch & Dr. Hans-Walter Lorenz, Business Cycle Theory A Survey of Methods and Concepts, The Second Edition Springer, Verlag Berlin Heidelberg, 1989, P: (48). [17]

These cases can be represented graphically as follows:

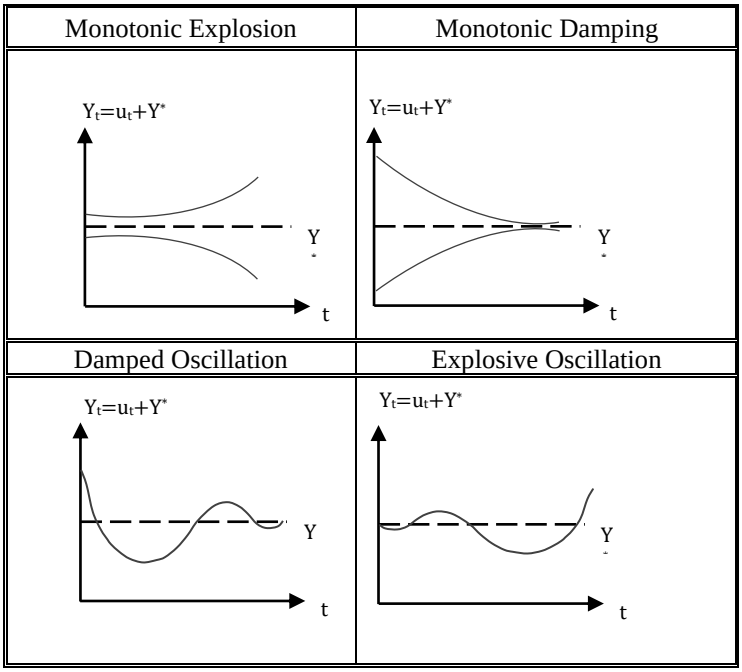

Figure (1). Possible causes of the national income resulting from the various interactions of the multiplier and the accelerator

Samuelson has extracted a graphic figure from the marginal propensity to consume and the accelerator values that he placed hypothetically to clarify the effect of their interaction on the nature and level of economic activity, and then represent the stages of the business cycle as a measure and indicator of it, as in the following graph:

* The formula $(((\beta(1+ă))^2 \geq 4\beta ă)$ has been simplified to $(\beta(1+ă)^2 \geq 4ă)$ by using the properties of the sign (≥).

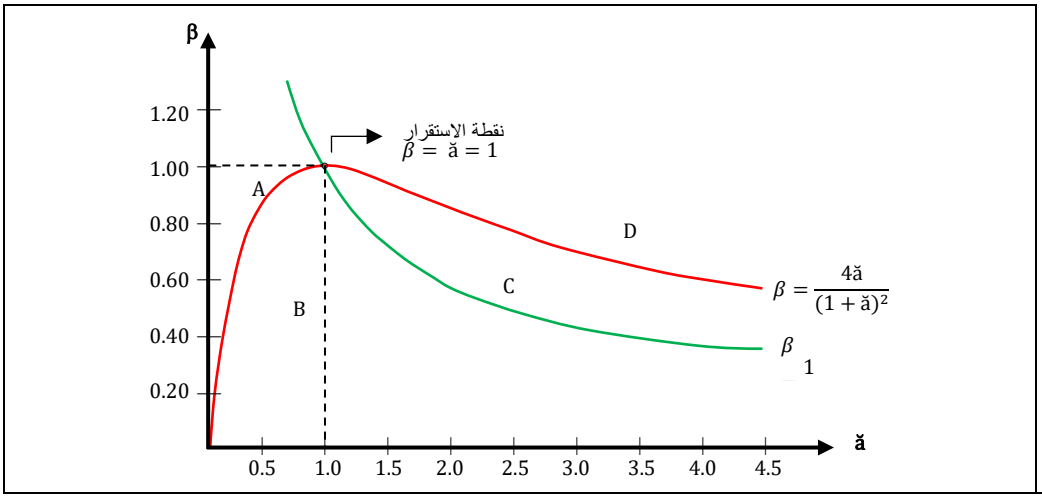

Figure (2). The interaction of multiplier and accelerator in Samuelson's model produces different trends for the national income

To illustrate this figure, Samuelson divided the figure into four sections. Each one represents a specific state of the economic activity that it can go through when each of the marginal propensity to consume and the accelerator intersects and achieve an interaction between them [18]. Where section (A) is the area of the multiplier, and the effect of the accelerator is limited because its value is close to zero, which means that the value of the multiplier determines the fluctuations in national income as a result of the change in the size of the government spending in this region ($\frac{1}{1-\beta}$) and Samuelson called this area The Keynesian, which is a stable area. Section (B) witnesses' fluctuations around the equilibrium income level due to the regular periodic changes made by the financial authority in government spending. As for area (C), it will witness growing and explosive fluctuations in the national income far from the equilibrium level in light of a constant level of government spending. And the final one (D) represents the explosive growth of the national income continuously due to the high values of both the marginal propensity to consume and the accelerator [(2)].

3. Application the Model

After examining the measurement mechanism that Samuelson came up with, it became possible to test the model by applying it to the French economy, and as follows:

1- Estimate the consumption function provided by Samuelson ($C_t = \beta Y_{t-1}$) (using the least-squares method) to obtain the marginal propensity to consume, which is necessary for calculating the multiplier and in calculating the values of (X1, X2) that determine the general direction of the business cycle, the test results came as follows:

i) The estimated consumption function ($C_t = 0.63Y_{t-1}$)• and this means that the marginal propensity to consume for the household sector is (63%) of the income, meaning that an increase in the national income by one unit leads to a rise in consumption by (0.63) company.

ii) The explanatory power of the estimated model came at (97%). It is high in a manner that raises the suspicion that there is a problem of self-correlation between the variables. However, this doubt is negated by the double test of Lakrang, which came at (39.77%). It is less than the value of (χ^2) of (52.82%). This means accepting the null hypothesis and rejecting the primary idea that states a problem, And the (h) statistic whose value came to (0.714). It is less than (1.96), which means that there is no linear correlation problem, i.e., acceptance of the null hypothesis.

8- For more, see:

- Paul A. Samuelson, Interactions between the Multiplier Analysis and the Principle of Acceleration, OP, CIT, P: (77).
- Paul A. Samuelson, a Synthesis of the Principle of Acceleration and the Multiplier, OP, CIT, P: (793).

*The reader may notice that the marginal propensity to consume is high in the French economy, but the validity of the estimated model can be inferred by relying on the research study below, which estimated the marginal propensity to consume in the long term to be (0.66) and in the short term (0.71):

➔ Suzanne Casaux and Pierre Ecochard, Private consumption in France – Stubbornly high, or responsive to determinants, ECFIN Country Focus, Volume (8), Issue (1), 2011, pages (1-8).

2- After obtaining the value of the marginal propensity to consume, it became possible to compute the multiplier value as an essential step in Samuelson's model. According to the simple formula that Keynes came up with first, its value is (2.703).
3- Calculate the value of the accelerator by dividing the importance of the investment variable (total capital formation) by the change in consumption, i.e. ($ă = \frac{I_t}{(C_t - C_{t-1})}$). This is to obtain a series of the accelerator values necessary in extracting (U_t) values that measure the general direction of the business cycle. Its value as an average was estimated (3.3) for the whole time series, meaning that every increase in the national income by one unit will speed up capital accumulation by the accelerator amount. So, the change in consumption is responsible for explaining the total capital accumulation changes, defined by the explanation factor (R^2), whose value was (86%).
4- After obtaining the calculated and estimated values of the Samuelson model, we can review the economic fluctuations that occurred during the studied and historically documented period and compare them with the results obtained to ensure the reliability of this model in measuring these fluctuations over time.

The studied period witnessed many economic fluctuations that have affected most countries' economies, according to the degree of both of its connection and its contribution to the volume of foreign trade. The second recessionary inflation crisis that hit European countries during the period (1981-1984) had a more significant impact and intensity than its predecessor and made the economy suffer from a fluctuation that continued until the late eighties of the last century. The center of the capitalist system (the United States economy) strengthened the depth of these economic fluctuations that the French economy suffered.
Perhaps the most well-known is the 1982 debt crisis that afflicted Latin American countries. It precipitated a wave of global economic stagnation and catalyzed another problem during 1986–1989, as oil prices declined. Thus, the American energy institutions that significantly affect the US economy and those of other oil-producing countries such as Norway, Venezuela, and Mexico are paralyzed.
During this period, another crisis happened in 1987: a financial and monetary crisis represented by the collapse of the stock prices. The problem started from Hong Kong moving to Europe and then the United States (especially the stock market of Wall Street), called later The Black Monday. This crisis was followed by a similar situation in the United States of America two years later, i.e., in 1989, due to a sudden collapse of the stock and bond prices in the US financial markets[9, 19].
In general, the period from the end of the seventies until the end of the nineties has witnessed many financial and monetary crises represented by; the exchange rate crisis during the period (1975-1987), other banking crises during the period (1987-1997). the total number of these crises was estimated at approximately (158) problems that were mainly caused by the policies of financial liberalization and the restructuring of the banking system of Latin American countries [20, 21]. This era of crises set the stage for a global recession that contributed to the creation of a significant economic crisis after a rapid and effective growth rate in the Asian tiger economies that sparked from the economy of Thailand to spread like wildfire in the rest of the Southeast Asian economies of similar nature in 1997 [22]. What made the global economic recession worse during this period is the decline in the Asian tiger's imports, which negatively affected the exports of the major industrialized countries, the most important European countries (represented by France, Britain, and Germany). The United States was affected by this crisis and suffered from a deficit in its trade balance of 176 billion US dollars in 1998, which reflected negatively on the global economic growth rate, reaching its lowest levels during the same year [23].
Soon after the global economy emerged from the Asian tiger's crisis, a new problem started after September 11th of 2001, which generated a wave of economic impacts that reflected on the economy as a whole. These events have led to an increase in fuel and gas prices and a decline in the dollar against other leading currencies. The Euro affected the monetary sector in the economies of the euro area, leading to a decrease in the volume of trading in the London Stock Exchange by 5.7%. This, in turn, affected the French real sector directly [24]. At the beginning of 2006, the features of the birth of a new crisis have started, represented by low-interest rates and high prices of real estate in the United States of America, followed by the inability of borrowers to pay. In 2008 the economic crisis erupted, and the economic indicators continued to decline and reach their lowest levels until 2009. This crisis has affected all other economies, the most important of which are the major economies.
In contrast, The Financial Times Composite Index of European financial markets declined by (32.1%), which led to a significant decline in the economic growth rate. This crisis pushed the United States and other affected countries to take several government actions, represented by increasing the government spending and subsidizing the companies and banks that declared bankruptcy. Which generated a significant deficit in the budget of the countries that followed this expansionary policy, where (80%) of the eurozone economies suffered from a debt exceeding the agreed limit (3%) of the gross domestic product in the Maastricht Agreement, and this is indicated by the percentage of the French budget deficit, which amounted

(7.2%) of its GDP in 2009 [24, 25]. The global economy did not recover from the previous crisis, and many countries remained suffering from its effects, especially the European Union countries. Their suffering continued until a new crisis erupted that led to the entry of the Eurozone economies into a recent economic recession officially in 2013. This crisis started from the Greek economy after its confession in 2010 that the figures of economic indicators of growth and indebtedness are incorrect, and they are unable to pay their debts, which led to the shaking of the entire eurozone economies because of its single monetary system. Greece was followed by several other European countries such as Italy, Spain, Ireland, Portugal, Spain, and even the United Kingdom, which led to the rapid transmission of the effects of this crisis to the rest of the other world economies [24].

The lack of institutional and financial capacity among the various European economies has contributed to deepening and prolonging the recession. Therefore, we find that the European countries have resorted in (2010) to the establishment of a mechanism called (Facilitating the European Financial Stability), which aims to achieve financial stability for the economies of the Eurozone by providing temporary financial assistance to the member states, with amount up to 440 billion euros. Another stabilization mechanism for non-member states is also quick and complements the previous agent. This mechanism allows the European Union Council to help the economies of the European Union countries that have an independent monetary system by allowing them to borrow from the financial markets without exceeding the limited amount of (60) billion euros guaranteed by the joint budget. Despite these expansionary actions that this region and the world have witnessed, the recession was still ongoing due to the pessimistic visions that prevail in the investment sector. It remained floundering and unable to achieve high growth rates, despite the reform programs adopted by these European Union countries, whose economies did not emerge from this crisis until 2016 [26]. Returning to the results obtained from the measurement process conducted by the researcher, it can be said that the Samuelson model was able to accurately measure the business cycle in comparison with the history of the economic fluctuations that happened in the world of which the French economy is a part. When drawing the results of the national income of the French economy that was measured using the mentioned model, this becomes evident to the readers.

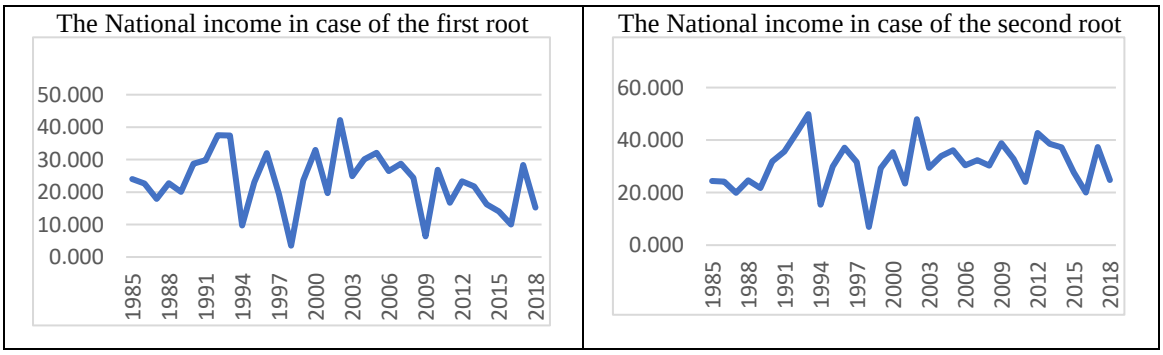

Figure (2). The Estimated French national income using the Samuelson model
Source: Prepared by the researcher based on the outputs of the Samuelson model applied to the French economy, which is mentioned in Appendix (1).

The previous figure (2) shows that the French economy has been exposed to many economic fluctuations during the studied period. In addition to the Samuelson model, which generates two fundamental values of the calculated national income being $(\beta(1+ă)^2 \geq 4ă)$. However, the findings obtained are comparable and did not demonstrate a significant difference except in (2009). This means that the measured effects of the first root more accurately describe the phases of the market cycle. This situation, which occurred several times during the studied period.

Table (2). The number of business cycles measured during the studied period

The business cycle	Length of cycle	The extent of the Contraction	The size of the Expansion
The First	1985-1994	1985-1989	1989-1994
The Second	1994-1998	1994-1996	1996-1998
The Third	1998-2002	1998-2000	2000-2002
The Forth	2002-2009	2002-2006	2006-2009
The Fifth	2009-2016	2009-2013	2013-2016
The Sixth	2016- unspecified		

Table (2) shows that the French economy went through five cycles, with specified beginning and ending. Some of them were external cycles and moved directly to France, one of the world's most significant major capitalist

economies. This means that the French economy has a great degree of association with other world economies that can affect and be affected by any economic crisis that may occur. This was evident after the European sovereign debt crisis that erupted after the mortgage crisis in the United States of America.

4. Conclusions

Samuelson's model can measure and determine the extent of the successive business cycles on the French capitalist economy during the studied period accurately and objectively. Samuelson's model, which was applied to the French economy, generates two natural solutions for the national income being $(\beta(1+ă)^2 \geq 4ă)$. Also, the business cycle is a type of monotonic explosion since the calculated accelerator value is greater than the estimated marginal propensity to consume $(ă > \beta)$. The number of cycles measured during the studied period is five cycles with a specific time range and one with an indefinite end so that each process begins with a crisis and ends with another.

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