Using Fuzzy Logic Method to Investigate the Effect of Economic Sanctions on Business Cycles in the Islamic Republic of Iran

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1. Introduction

Currently, the world’s economies are experiencing economic fluctuations, including periods of prosperity and recession. In economics, there is a time gap between consumption and investment. This distance causes regular fluctuations in the economy. Business cycles do not mean specific fluctuations specific to a sector or part of an economy; rather, business cycles are the set of economic movements or the movement of a country’s Gross Domestic Product (GDP) [1]. A business cycle may take several years to be able to go through periods of prosperity and recession. A cycle begins with a period of economic prosperity. This period occurs in most economic activities and causes a period of recession. Those series of changes are repeated over and over again and have a regular and periodic state [2]. Each business cycle consists of 2 stages. These periods include boom and bust. A recession occurs after the boom period. In this case, the total production and prices of goods are reduced [3].

There are various theories about the causes of business cycles. Some attribute these cycles to the internal affairs of countries. They believe that these cycles are rooted in internal problems. Another group believes that the basis of business cycles is foreign intervention. That is imposed on the economy from outside [4]. Iran’s economy has faced extensive external interference since the formation of the Islamic Revolution. One of the most effective of these interventions is economic sanctions against Iran [5]. The purpose of sanctions is to put pressure on the target country to change behavior. This behavior change can be political or economic. Economic, financial, and technological tools are useful for foreign policy and achieving goals. Among the types of sanctions, economic sanctions are the most used in the world among countries. There are different types of economic sanctions: export tariffs, import quotas, ban on
trade relations, and creation of non-tariff barriers to imports [6]. There are different views on the impact of economic pressures. Statistical studies can measure the effectiveness of these policies. Iran has always been subject to various political and economic sanctions by western countries. And it witnesses special and unique economic conditions that have not occurred in the world. Therefore, to meet the economic challenges, there is a need for innovation and brainstorming by experts. The purpose of this article is to examine the economic sanctions on business cycles in Iran. Therefore, to meet the economic challenges, there is a need for innovation and brainstorming by experts. The purpose of this article is to examine the economic sanctions of business cycles in Iran. It is necessary to define a time series for sanctions to study the sanctions and their economic effects. In previous studies, DUMMY variables incorporated the embargo effect into the model. In this article, the sanctions index identifies the effect of sanctions on the economy. The fuzzy logic method allows the researcher to consider a wide range of ideas to quantify the indicators. Sanctions imposed on Iran since 1979 have affected various sectors of the economy. The aspect to consider is the economic aspect of sanctions. Therefore, first, according to the failure points in the macroeconomic variables, questionnaires were developed. In these questionnaires, experts provided their views on the impact of each of the sanctions imposed on Iran on the variables of GDP, unemployment rate, and inflation rate. The experts in this article are 15 activists in the field of sanctions economics. They were doctoral graduates in international economics and university professors. Triangular fuzzy numbers diminished the opinions of experts. After that, according to three inputs and one output, a fuzzy system was designed.

In this article, after the introduction, there is a review of studies in sanctions economics. Then, the theoretical foundations of economic sanctions and trade cycles are presented. The fuzzy logic method is expressed. Then, the results are obtained. And outputs are introduced. In the last part, conclusions are presented based on the results of the research method.

2. Materials and Methods

2.1. Theoretical Foundations. The term business cycle or economic cycle refers to fluctuations in the economy in production or economic activity over several months or years. These fluctuations occur for long-term growth trends and typically include changes over time, between relatively rapid economic growth periods (expansion or boom) and periods of relative stagnation or decline (contraction or recession) [2]. The most common concept of business cycles is Lucas (1977). In his article "Recognizing Business Cycles," he considers business cycles as repetitive deviations of real GDP around its long-term trend. According to Lucas, understanding these types of business cycles is the first step in designing stabilization policies. He believes that most business cycles have a common feature [4]. Dornbush (2002) also considers business cycles as regular ups and downs of prosperity and stagnation in economic activities around the path of long-term economic growth. According to him, business cycles are regular fluctuations in macroeconomic activities. Therefore, every observed fluctuation cannot be called a business cycle [7]. Economists such as Schumpeter (1912), Goldsmith (1969), McKinnon (1973), and Shaw (1973) believe that financial markets play a role in the process of economic development and growth. The differentiation of financial institutions is the reason for the difference between the growth rates of countries. Goldsmith is one of the first researchers to show the positive impact of financial development on economic growth and to explain the channels through which markets and financial institutions affect economic development [2]. Business cycles are fluctuations related to the whole economy [8]. On the other hand, business cycles with oscillations in the economy are also seasonally different. Cyclical movements appear like waves in all economic activities since a time lag shows their effects on the whole economy [9]. Business cycles have 2 stages: the period of economic prosperity and the period of economic recession [1]. William Stanley Jones believed that fluctuations are periodic and last for a cycle of ten to eleven years. Cycles and business cycles are due to changes in the intensity of sunspots. In other words, the root cause of this phenomenon is related to factors outside the system [10]. After Jones, Henry Moore wrote a book in 1914 on the effects of climate change in economic activity, citing cyclical movements in climatic conditions as the cause of business cycles. According to Moore's theory, with the emergence of cyclical movements in climatic conditions and rainfall, the total product is affected. This factor plays a large role in the emergence of business cycles [8].

2.2. Business Cycle Demand-Side Theories

(i) Keynesian theory: according to this theory, total supply has a considerable elasticity. Monetary wages are sticking down. However, when aggregate demand decreases, real wages do not reduce, but output decreases rapidly. On the other hand, as aggregate demand increases, the aggregate supply curve will move quickly upwards. Therefore, as aggregate demand decreases, stagnation occurs, and as it increases, prices will rise. In the Keynesian system, there is no market mechanism. The supply and demand for money determine the interest rate. The decision to invest depends mostly on the "animal" spirit. Prosperity and recession will be caused by more or less trust in production units. Demand for labor does not decrease when confidence is low, because they may face trade union resistance or wage stickiness [1].

(ii) Monetarism theory: polygons generally believe that when monetary prices and wages are adjusted, the economy will return to potential real GDP. They believe that the adoption of monetary policy will cause the economy to cycle. Thus, real GDP and employment increase or decrease over time. Polygon believes that as long as the growth of money is
stable, the economy is inherently stable. The balance will be established by itself [2].

(iii) Theory of rational expectations: there are two models of rational expectations. 1. The New Classical Theory: according to the new classical theory, trade fluctuations are due to unpredictable total demand shock. An undefinable increase in aggregate demand reduces real wages, and monetary prices often regulate the price level. 2. New Keynesian theory emphasizes the nature of long-term resource contracts in this model. Employment contracts usually last between two and three years. The contract period for data and raw materials is between six months and two years [8].

According to the new Keynesian model, unpredictable changes in aggregate demand are like the new classic model. But because of time constraints, Keynesians believe that a change in aggregate demand could lead to employment cycles and real GDP. New classics argue that contracts can change quickly, given the predictable changes in aggregate cycles and real GDP. New classics deliberately abandon structural considerations and, based on statistical evidence, believe that interest rates can play a useful role in the emergence of cyclical fluctuations [9]. It said that resources are efficient in all markets. In this school, all markets in the short and long term follow the basic principles of supply and demand, and the policies of monetary authority are ineffective. Therefore, the hypothesis of rational expectation and its application in macroeconomics does not replace Keynesians and polynomials. This hypothesis has not accepted and rejected the phenomenon of periodic unemployment [4].

(3) Keynesian theories of the business cycle: according to this view, existing friction, which prevents rapid adjustments to stress, is an opener factor in the emergence of the business cycle in employment and output. This view holds that, under normal circumstances, monetary policy is a potent and more useful tool for economic stabilization than fiscal policy. Therefore, fluctuations around their continuous and long-term trends are examined [8]. However, it is necessary to pay attention to the limitations of the stabilization policy. That is, long-term interruptions in fiscal policy and long-term interruptions in monetary policy should be considered [12].

(4) Atmospheric theories related to the business cycle: the first theories regarding the business cycle were exogenous cycles. These theories relate business cycle to other business cycles created in nature, such as climatic conditions, which can be influenced by stars. These economists believe that these natural phenomena can affect tangible things such as agricultural products or intangible things such as people's moods, which will cause fluctuations in the economy. According to these economists, since these natural phenomena have a cyclical nature, they can create an economic cycle [7].

Haroud (1936) in his article entitled “Business Cycle” deals with the relationship between the incremental coefficient and its dynamic characteristic, which is the principle of investment acceleration. Due to the increase in investment, income increases. Demand for goods and services increases. This will further increase investment. And this cycle continues. In the following years, Haroud continued to expand his analysis and deal with its dynamic forms. Harold continued his research. Samuelson (1939), Metlers (1941), and Hicks (1950) endorsed him. Due to the presence of Harrod and Hicks at the University of Oxford, and later studies by Cambridge Keynesians such as Caldon (1940) and Goodwin (1951), this research process became known as the “Axis Bridge” of the Keynesian revolution.

Therefore, as mentioned in the form of different theories of the business cycle, it can be said that although business cycles have common components in general, they are not similar to each other and therefore they cannot be expressed by one factor and one mechanism. Although business cycles have a lot in common, they are not similar to each other. In general, all real, financial, and expectation variables are important in the emergence of these fluctuations. The reason for the emergence of the business cycle is not in the form of a theory. By understanding the reason for the emergence of this business cycle, economic conditions can be better and more accurately predicted [12].
In this article, the sanctions index was extracted. Using this index, the economic effects of sanctions can be studied. Slowly to have a wide range of people's opinions, the fuzzy logic method was chosen as a verbal-numerical interface to index economic sanctions against Iran. Questions were included in the questionnaire. Five fuzzy options were given to individuals to gather their opinions in more detail. Table 1 shows the fuzzy propositions and their numerical equivalents.

After that, according to the table of numerical equivalents of fuzzy propositions, the geometric average of the opinions of 15 experts in the field of sanctions economics on economic sanctions against Iran was collected and used as preliminary data. In these questionnaires, individuals were asked to comment on the impact of sanctions on production, inflation, and unemployment. In these questionnaires, the sanctions are listed by year and according to the sanctioning institution. Sanctions imposed on Iran since 1979 have affected various sectors of the economy. Therefore, first, according to the failure points in the basic macroeconomic variables, questionnaires were developed.

2.4. Fuzzy Logic. Fuzzy logic is an approach to computer science. Its main idea was first proposed by Professor Lotfizadeh in the 1960s. Fuzzy logic 0 and 1 are assumed to be the limit states of a fact, and in the meantime, it puts several manual states. The table of fuzzy equivalents for verbal preferences can be seen in Table 1. The most widely used fuzzy number is its triangular type [13]. This number has three components, Low, Medium, And High, which are shown in equation (1). The membership function of triangular fuzzy numbers is in the form of equation (2) [14].

The steps of fuzzy logic are as follows:

Step 1 in this step, verbal variables are considered as input and output. This data was collected through a questionnaire from 15 activists and experts in the field of sanctions economics. Linguistic criteria are used in this method according to Table 1 [15].

Step 2 in this step, it is necessary to define the appropriate membership function for fuzzy verbal data. In most studies, the triangular membership function is used. Therefore, in this article, to extract data related to the sanctions index, an economic triangular membership function was used.

Step 3 in this step, it is necessary to determine the rules governing fuzzy logic. Therefore, the researcher to the fuzzy system [16] must apply appropriate rules.

Step 4 obtaining fuzzy values, in this step, according to the completed questionnaires, the input values were applied to the fuzzy system and were obtained for the output of fuzzy data.

Step 5 in this step, it is necessary to perform diffusion operations to convert fuzzy data to numerical data [17].

Figure 1 shows the general structure of a fuzzy system and its components.

3. Results and Discussion

After collecting the fuzzy questionnaires, each of the verbal propositions according to Table 1 was equated with a triangular fuzzy number. After that, according to the three inputs and one output, the fuzzy system was designed.

Table 2 shows the values of fuzzy input data of the questionnaires. These data are the result of the geometric average of the opinions of all economic actors and experts in the field of sanctions economics.

In this paper, to extract the sanctions index, a fuzzy logic system with three inputs and one output was first designed. Figure 2 shows the membership function for each component of this triangular fuzzy system.

The fuzzy input values were then designed into a fuzzy system with three inputs and one output, and Table 3 shows the fuzzy output values of the economic sanctions index designed from the fuzzy system.

Table 4 shows the time series of data related to Iran's economic sanctions index.

At this stage, after extracting the data related to the number of sanctions, using this data, the effect of economic sanctions against Iran on the structure of business cycles was examined. The variables used in this study were obtained by the library method from the World Bank. The model variables are as follows: GDP; gross direct product-inflation; I: investment; G: government expenditure; NX: net exports; sanction: an indicator of economic sanctions. To investigate the effect of sanctions on the structure of business cycles in Iran, two scenarios were used. In scenario 1, GDP corresponds to equation (3). In scenario 2, the effect of sanctions was added to the GDP model and the estimate was made following equation (4).

The Hodrick–Prescott filter was used to extract business cycles in this paper. The cyclical trend of GDP (yt) is obtained through the Hodrick–Prescott dual filter. Adjusting the sensitivity of the trend to short-term fluctuations is achieved with the smoothing parameter $\lambda$. In this study, due to the use of annual data, the value of the parameter $\lambda = 16$ was considered. This method minimizes the variance of time series around the trend. To achieve a cyclical movement, other components of the GDP cycle must be eliminated. GDP (yt), including long-term trends (Tt), cyclical movements (Ct), and irregular movements (shock) (It), are as equation (5).

The HP filter is used in two steps to separate these components. First, the time series of GDP is broken down and the long-run trend (Tt) disappears in equation (6).

By subtracting the trend from the original series (yt), we get a new series (Zt) that contains cyclic and irregular components in equation (7).

In the second step, using the HP filter again on Zt, a smooth component is obtained, which is a cycle (Ct). The difference between Zt and Ct represents the shock or irregular components (It) according to equations (8) and (9) [8].
The output values of the scenario autoregression estimate research are shown in Table 5. According to the values obtained from the estimation of equation (3), it can be said that the coefficient related to inflation is negative and significant and is acceptable according to economic theories. If inflation increases, GDP will decrease. The coefficient obtained for investment is positive and significant and indicates that, with an increase in investment of one percent, GDP will increase to 11.68 percent. The value of the coefficient obtained for government spending is positive and statistically significant, and it can be said that, with a one percent increase in government spending, GDP will increase by 0.00027 percent. The coefficient obtained for net exports is negative and significant. Also, GDP with three interruptions affects GDP and its coefficient is positive and statistically significant.

After estimating the research model according to a research scenario, the output values of the autoregression method for GDP are obtained, and the output of the HP filter for these values is shown in Figure 3. Figure 3 shows a blue diagram of the output values of the autoregression estimate of a research scenario. The red graph shows the trend of changes in GDP. The green chart shows the fluctuations in GDP around zero.

The output values of the self-regression estimation scenario are two studies according to Table 6. In this estimation, the effect of economic sanctions is removed from the structure of Iran’s economy as a positive shock to examine the main trend of Iran’s economy without sanctions. The results of autoregression estimation showed that inflation with a negative and significant coefficient affects GDP. The coefficient obtained for investment shows that, for a one percent increase in investment, GDP will increase by 13.8 percent. This coefficient is statistically significant. Also, the coefficient obtained for government spending in Iran shows that, for a one percent increase in government...
spending, GDP will increase to 0.00023 percent. This coefficient is statistically significant. The estimated coefficient for net exports is negative and significant. The coefficient obtained for the sanctions number is positive and significant. Besides, the third and fourth interruptions of GDP affect GDP in Iran and the coefficient obtained for it is positive and significant.

After estimating equation (4) by the autoregression method, the output values were analyzed by the HP filter. The output of this filter is as shown in Figure 4.

In Figure 4, the blue graph shows the output values of the autoregression estimation of scenario 2 of the research. The red graph shows the changing trend in GDP. The green chart shows the fluctuations in GDP around zero. Also, the boom and bust cycle in scenario 1 and scenario 2 is shown in Table 7.

\[
A = (\text{low} - \text{medium} - \text{high}),
\]

\[
\mu_{A^*}(x) = \begin{cases} 
\frac{x - L}{M - L}, & L \leq x < M, \\
\frac{H - x}{H - M}, & M \leq x < H, \\
0, & x < L \text{ or } x > H,
\end{cases}
\]

\[
\text{GDP} = f (\text{inflation}, I, G, NX),
\]

\[
\text{GDP} = f (\text{inflation}, I, G, NX, \text{sanction}),
\]

\[
Y_t = T_t + C_t + I_t,
\]
### Table 3: Output data from the fuzzy system.

| Output data: sanction index | Low   | Medium | High   | Fuzzy data |
|-----------------------------|-------|--------|--------|------------|
| 1                           | 1.42  | 1.84   | 6.35   | 3.21       |
| 2                           | 1.19  | 2.13   | 4.66   | 2.66       |
| 3                           | 1.15  | 7      | 7.11   | 5.08       |
| 4                           | 1.38  | 1.78   | 1.91   | 1.69       |
| 5                           | 2.30  | 2.46   | 7.43   | 4.06       |
| 6                           | 1.33  | 6.80   | 7.23   | 5.12       |
| 7                           | 1.07  | 6.69   | 8.40   | 5.39       |
| 8                           | 2.65  | 3.55   | 6.91   | 4.37       |
| 9                           | 1.07  | 5.05   | 6      | 4.04       |
| 10                          | 1.54  | 3      | 7.26   | 3.93       |
| 11                          | 6.95  | 8.03   | 8.35   | 7.78       |
| 12                          | 7     | 7.99   | 8.84   | 7.94       |
| 13                          | 7.35  | 8.03   | 8.69   | 8.02       |
| 14                          | 7.11  | 7.47   | 9      | 7.86       |
| 15                          | 5.46  | 5.71   | 7.99   | 6.39       |
| 16                          | 6.69  | 7.11   | 8.55   | 7.45       |
| 17                          | 7     | 7.35   | 7.47   | 7.27       |

### Table 4: Sanction index data for Iran.

| Sanction index data | Year | Sanction index | Year | Sanction index | Year | Sanction index |
|---------------------|------|----------------|------|----------------|------|----------------|
|                     | 1979 | 3.211614       | 1993 | 4.331441       | 2007 | 5.860179       |
|                     | 1980 | 2.9383         | 1994 | 4.595396       | 2008 | 7.784207       |
|                     | 1981 | 2.664987       | 1995 | 5.123305       | 2009 | 7.856574       |
|                     | 1982 | 3.271227       | 1996 | 5.391473       | 2010 | 7.947141       |
|                     | 1983 | 3.877467       | 1997 | 4.374773       | 2011 | 7.988276       |
|                     | 1984 | 5.089946       | 1998 | 4.292395       | 2012 | 8.029411       |
|                     | 1985 | 4.241109       | 1999 | 4.210017       | 2013 | 7.864564       |
|                     | 1986 | 3.392271       | 2000 | 4.127639       | 2014 | 6.393815       |
|                     | 1987 | 1.694595       | 2001 | 4.045261       | 2015 | 6.658696       |
|                     | 1988 | 1.991207       | 2002 | 4.017983       | 2016 | 6.923576       |
|                     | 1989 | 2.287818       | 2003 | 3.990706       | 2017 | 7.188457       |
|                     | 1990 | 2.881041       | 2004 | 3.977067       | 2018 | 7.453338       |
|                     | 1991 | 3.474263       | 2005 | 3.963429       | 2019 | 7.277496       |
|                     | 1992 | 4.067486       | 2006 | 3.936151       |      |                |

### Table 5: Results of autoregression estimation scenario 1 research.

| Variable   | Coefficient | T-statistic | Prob. |
|------------|-------------|-------------|-------|
| Inflation  | -7/17       | -0/73       | 0/47  |
| $I$        | 11/68       | 1/56        | 0/12  |
| $G$        | 0/00027     | 1/43        | 0/16  |
| NX         | -3/24       | -0/54       | 0/59  |
| $C$        | 8/23        | 0/44        | 0/65  |
| AR (1)     | 1/47        | 7/01        | 0/00  |
| AR (2)     | -0/69       | -2/70       | 0/01  |
| AR (3)     | 0/17        | 1/05        | 0/29  |
| SIGMASQ    | 1/20        | 4/24        | 0/0002|

$R$-squared = 0/94

\[ F\text{-statistic} = 66/98 \]

\[ S.E = 3/97 \times E + 10 \]

Durbin–Watson stat = 1/82
Figure 3: Hodrick–Prescott filter output for a research scenario.

Table 6: Results of autoregression estimation scenario 2 research.

| Variable    | Coefficient | $T$-statistic | Prob. |
|-------------|-------------|---------------|-------|
| Inflation   | $-1/13$     | $-1/28$       | 0/21  |
| I           | 13/80       | 2/15          | 0/04  |
| G           | 0/00023     | 0/86          | 0/39  |
| NX          | $-3/79$     | $-0/59$       | 0/55  |
| Sanction    | 1/83        | 2/04          | 0/05  |
| C           | 1/98        | 0/10          | 0/92  |
| AR (1)      | 1/40        | 7/50          | 0/00  |
| AR (2)      | $-0/7$      | $-2/86$       | 0/008 |
| AR (3)      | 0/36        | 1/31          | 0/19  |
| AR (4)      | 0/14        | $-0/73$       | 0/46  |
| SIGMASQ     | 1/05        | 3/73          | 0/009 |

$R$-squared = 0/95  \quad \quad F$-statistic = 57/67

$S.E = 3/84*E + 10$  \quad \quad Durbin–Watson stat = 1/89

Figure 4: Hodrick–Prescott filter output estimation of two research scenarios.
4. Conclusions

Sanctions have prolonged the economic downturn in Iran. Compare it to other countries in the world. In this article, the index of economic sanctions was calculated. Using fuzzy logic, the effect of sanctions on Iran’s economy was studied. The results show that the sanctions imposed on the Islamic Republic of Iran in 2012 had the most negative economic effects on the Iranian economy. After that, according to the values obtained for the sanctions index, the sanctions imposed in 2011 were able to greatly affect the Iranian economy. This trend shows that, over time, sanctions have had more severe consequences. Then, using the self-regression method, the Iranian demand side was examined. The results show that, in scenario 1 of the study, in which the model was studied despite economic sanctions, increasing inflation will reduce the level of GDP. Also, the more investment there is in the country, the higher the GDP will be. An increase in government spending in the economy will lead to an increase in GDP. In scenario 2 of the study, the effect of sanctions was removed from the economy and with the help of the economic sanctions index, it was assumed that there are no sanctions in the Iranian economy. Under these circumstances, the results showed that if the effect of sanctions is removed from the economy, for every one percent that the effect of sanctions decreases, GDP will grow by 1.83 percent. That is, if there are no sanctions in the Iranian economy, the recession will be shorter and the boom will be longer. The output results of the HP filter for research scenarios showed that, in scenario 1 of the research, the periods of the recession were shorter and the Iranian economy experienced a period of greater prosperity. Meanwhile, the results of scenario 2 studies, which show the effect of economic sanctions against the Islamic Republic of Iran, show that economic sanctions have led to an increase in the depth of the economic recession and a longer period of economic recession in the Islamic Republic of Iran. According to the obtained results, it is recommended that economic policymakers increase the production capacity of the economy by protecting the economy against internal and external threats and fluctuations and provide the basis for reducing the length of the economic recession in the Islamic Republic of Iran.

Data Availability

All the data in this article can be published publicly.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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