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Decision making on financial investment in Turkey by using ARDL long-term coefficients and AHP

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Abstract

Mathematical modeling methods are frequently used for solving everyday problems. Decision making, one such method, can be used in every aspect of life for different scales such as micro (households), medium (companies), and macro (states) decisions. Due to the large number of parameters affecting decision, it is possible to make mistakes in the selection of the appropriate investment instrument with classical methods; hence, scarce resources may be wasted, and sometimes it may even be impossible to make a decision. This study seeks to answer the question "Which financial investment instrument should be selected under the current conditions?" using decision making problems. Factors affecting gold, USD, and EURO, which are selected as the financial investment instruments in Turkey, are examined using the autoregressive distributed lag (ARDL) bound test. The selected variables are monthly and belong to the January 2009 to May 2018 period. The ARDL results show that the selected financial investment instruments are affected by most of the factors separately. By using the coefficients obtained from the ARDL model, the analytic hierarchy process (AHP) model was established. According to the results of the model, the EURO was determined as the most suitable financial investment for Ahmet and others with the same preferences.

Keywords: Decision making, Financial investment instruments, ARDL, AHP

Introduction

The remainder of an individual's income post consumption constitutes their savings. The savings are a source for investments, ensuring the continuity of the economy in a holistic manner. The main objective in converting savings into investments is to obtain additional income while avoiding the depreciation of assets due to facts such as inflation.

In the past, investment instruments were limited to precious metals such as silver and gold. Due to the challenges in the use of precious metals in trade, paper money and the banking system emerged, resulting in countries starting to use their national currencies. Thus, money and capital markets have evolved with the increase in transaction volume and opportunities in the communication system. Consequently, new

financial investment instruments (foreign currency, deposit interest, stock, bonds, etc.) have been added to traditional ones (precious metals, etc.), creating the investment instruments of today. Therefore, many investment instruments have become available in financial markets for individuals to evaluate their savings options. This has raised the question, "Which investment instrument should be selected under the current conditions?" To answer this question, the factors affecting financial investment instruments should be determined first.

Several hypotheses and theories have been presented to answer the questions of how security prices change in financial markets and what affects price changes. Markowitz (1952) developed the modern portfolio theory (MPT) to determine how a rational individual would create a portfolio to ensure high returns when making an investment decision. Before Markowitz (1952), economists (Keynes and others) considered distributing portfolios as wrong because they believed the investors had insufficient experience. Therefore, they encouraged investors to use the investment instruments they were accustomed to. In contrast, MPT determines the best possible portfolio by distributing it according to the selected risk level. In fact, it suggests that it is more logical to use investment instruments in different sectors rather than use the ones in the same sector when distributing portfolios (Fischer 2019). The core point of MPT is that high return comes with high risk.[1]

Capturing the many basic points of MPT, Eugene Fama (1965) and Paul A. Samuelson (1965) developed the efficient market hypothesis (EMH) in the 1960s. Completing Markowitz's (1952) MPT, EMH provided diversity through the concept of indexing or a broad-based market index by holding an array of stocks without having to select individual securities (Fischer 2019).

According to EMH, financial markets are effective in terms of activity, resource allocation, and information distribution. In other words, there is no cost for security supply and demand in the market; market resources are optimally distributed and prices in the market reflect all information. In addition, it is given that investors in the market are rational individuals who have full and precise information and try to maximize their benefits (Bayraktar 2012).

According to Fama (1965), since prices act according to the random walk model, they will fluctuate around their real value and eventually reach the real value (Delcey 2019). In the random walk model, since the prices move randomly, the future estimation cannot be made with available data. Therefore, it is impossible to estimate the future prices of securities using technical analysis in the market (Yıldırım 2017).

Roberts (1967) stated that the effectiveness of markets is categorized into three different levels based on different information sets. These are (Fama 1970; Malkiel 1989):

- Weak form: Current prices in the market are considered to reflect all information from past prices in the market.
- Semi-weak form: Market prices reflect public information in addition to past prices.
- Strong form: All information about the prices in the market is available to all investors and the prices reflect this information.

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[1]http://euronomist.blogspot.com/2013/02/efficient-market-hypothesis-vs-modern.html E.t.: 19.03.2020

Therefore, even in the weakest form, the prices in the market are permanently at the equilibrium price. If the equilibrium price deviates from its original level, the market factors will work quickly to bring the price to the new equilibrium level. Consequently, no investor can make excessive profit using the information in the market.

In the late 1970s, discussion began on how effective the markets are because of the "bubbles" that appear in the markets, and also whether all investors are rational individuals like the theories suggest. In other words, an ordinary investor who has just entered the market and an investor who has spent years in this business cannot be expected to make a decision with the same rationality. In the 1980s, "behavioral finance" was established by the psychologists Kahneman and Tversky (1979), the founders of "prospect theory" which argues that the investor makes decisions based on the potential value of profit and loss rather than the profit of the decision, and Richard Thaler (1980) who is the finance theorist applied the prospect theory to economic issues first (Hammond 2015). Shefrin (2002) organized behavioral finance phenomena around three themes, which are:

- Heuristic-driven bias, which includes investors' biases that cause them to make mistakes.
- Frame dependence, which includes how decision-making problems are framed, which affects investors' perceptions of risk and return.
- Inefficient markets due to market prices that are affected by heuristic-driven bias and frame dependence.

Individuals who make financial investments will make mistakes. Behavioral finance can help investors identify and predict both their own mistakes and other investors' mistakes (Shefrin 2002).

The premise of behavioral finance is that investment decisions are made to satisfy the investor rather than maximizing the profit. Consequently, while examining the accuracy of the model put forward by empirical studies in traditional finance, it is also important to create models that explain the behavior patterns in the market based on behavioral finance (Sümer and Aybar 2016).

Whichever theory one follows, the primary purpose of an investor is to make profit, for which the investor has to choose an investment tool. In this context, decision-making is the process of selecting the most appropriate option by evaluating the important criteria among the available alternatives. In cases where there is too much data and too many alternatives, making a decision with the human mind may result in a wrong decision. In such cases, a mathematical model can be created to arrive at the most appropriate alternative. Many studies discuss decision-making methods that use mathematical modeling. Among these, the leading method is known as analytic hierarchy process (AHP), which was first described by Saaty (1977). Several other studies that examine models other than AHP are Al-Harbi (2001), Kou et al. (2014), Kou et al. (2019), Li et al. (2018), and Wang et al. (2008). Moreover, studies that apply decision-making problems for financial investment are Gerlein et al. (2016), Korczak et al. (2016), Nobakht et al. (2012), and Wei et al. (2005).

In this study, we created a model to help the investor select the most profitable investment instrument among several others. The model we used, which includes

different methods such as autoregressive distributed lag (ARDL), AHP, and L-Fuzzy sets, is a new method that has not been used before. The difference is that this is a multidisciplinary study that combines mathematical analysis with econometric analysis. To examine the usability of the model, we selected three different investment instruments, gold, USD, and EURO, which are the most preferred investment instruments in Turkey. We divided this paper into five sections. In Section 2, we examine the financial investment instruments that we selected to apply to our model. Section 3 provides information about the factors affecting these investment instruments. Section 4 provides a brief review of the literature. In Section 5, after providing information about the data and the variables, we first conducted econometric analysis to determine the factors that affect each of the selected investment instruments. We then provide information about the fuzzy soft sets and how to implement them into the decision-making algorithm. Section 5 illustrates the application of decision making for financial investment by using the results obtained from econometric analysis and the investment preferences of the selected investor. Section 6 concludes the study.

Selected financial investment instruments

In financial markets, an investor can find several instruments to invest in. For this study, we selected three different instruments, that is, gold, USD, and EURO. Although these instruments are in different sub-financial markets (i.e., gold belongs to the commodity market while EURO and USD belong to the foreign exchange market), these are the preferred investment instruments by Turkish people. However, this does not mean that the other investment instruments in Turkey are insignificant. We used the most preferred investment instruments in the country as examples to demonstrate the applicability of the method. Since how the investment instruments used in the model are affected by different factors is examined separately, the data used in the L-fuzzy set have been obtained separately for each variable. Therefore, using investment instruments belonging to different sub-markets would not be an issue. Consequently, one can check the profitability of different investment instruments of his/her choice by using this model.

Throughout history, gold has served different purposes such as being used in jewelry and a means of investment and exchange instrument. When gold money standard was applied, it was used as money in debt payments in international transactions (Öztürk 2011). Between 1870 and 1930, country currencies were represented by a certain weight of gold. However, as a result of the financial problems after World War I and in the 1920s, many countries printed money without control. Therefore, the gold money standard could not be applied and the price balance between countries was disrupted during the world wars. In the early 1970s, USD-gold convertibility was suspended and gold became an individual saving instrument instead of an exchange instrument. Although the developments in financial markets and the proliferation of alternative investment instruments have reduced the importance of gold as a means of value storage, people seeking secure ports have increased their demands for gold due to financial crises. This situation led to an excessive increase in gold prices during financial crises (Toraman et al. 2011; Karataş and Ürkmez 2013). As seen in Fig. 1, during crisis periods (1929, 1973, and 2008) gold prices increased significantly.

Fig. 1 Gold prices
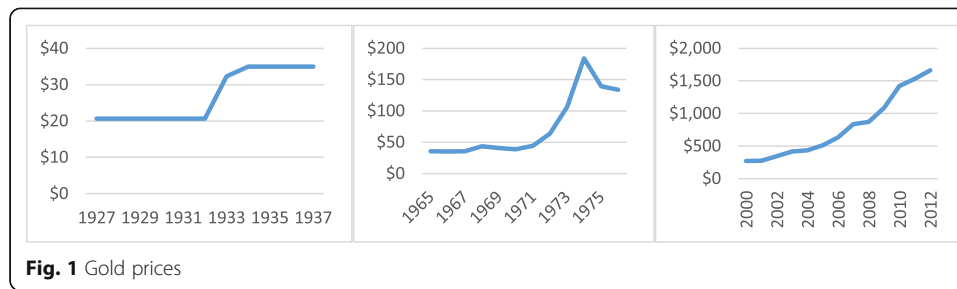
With the increase in the volume of world trade, the exchange mechanism, easily made by using precious metals such as gold and silver, had lost its functionality. As a result, countries began to print their own currencies and use these currencies in both national and international markets. The fact that each country has its own currency has led to the formation of the international currency market, resulting in gold losing its characteristic of being an instrument of exchange. Currencies, which were previously connected to gold and whose value depended on gold, began to take their own value. Foreign currency has become an alternative investment instrument due to its high usage and liquidity.

When making a decision to invest, liquidity of the investment instrument is very important. It should be able to be quickly converted to cash when needed. For this reason, in addition to gold, precious metals, investors also use the currencies of other countries. Since currencies of countries with strong economies do lose their value less than the other country currencies or not lose it at all, they play an alternative investment instrument role for investors in rest of the world. Due to the high rate of inflation seen in Turkey for many years, TL had failed to protect its value. For this reason, Turkish people have been investing their savings on currencies belonging to other countries as well as the precious metals such as gold. In this context, USD and EURO, which belong to the strongest economies of the world, stand out among other currencies because they are both reliable and highly liquid.

In addition to gold and foreign exchange, banks provided their depositors interest in a certain percentage of their deposits in exchange for keeping their deposits in their banks. The deposit rate is determined at the beginning of the period and shows how much money will be added to the original amount at the end of the period. Since the deposit interest is determined in advance, the profitability ratios of other investment instruments are taken into consideration while making an investment decision. If the return on other investment instruments is determined to be lower than the return on deposit interest, the investments are made on deposit interest.

Factors affecting the selected financial investment instruments

The return from the financial investment instruments is not only mutually dependent but also depends on the various factors that may arise in daily life. These factors are generally considered to be political factors, human behavior, and economic factors. Changes in these factors are very important for investors as they will affect the return on investment instruments and, consequently, their profitability.

Political factors

Political elements can positively or negatively affect the profitability ratios of financial investment instruments. Some of these political elements are:

- Economic policy followed by governments: The economic decisions taken by governments directly or indirectly affect the investment decisions of individuals. While government decisions to change the value of financial investment instruments (devaluation, interest rate cuts, etc.) have a direct impact on the profitability of these instruments, interventions on factors affecting these instruments (trade openness policy, import duties, etc.) indirectly affect profitability.
- Political uncertainty or crisis: Decision makers may make decisions to shift to less risky areas or delay or cancel their investments due to uncertainty. This causes changes in the returns from financial investment instruments.
- Policies of central banks: Central banks' policies such as changes in interest rates, changes in money supply, and direct intervention to exchange rates affect the profitability of financial investment instruments.

Human behavior

The intrinsic characteristics of human beings is that their economic expectations in daily life and their decisions regarding these expectations always change. Rumors, experiences, and habits are important factors in influencing these decisions. Nevertheless, rational individuals make their investment decisions by considering economic and political factors. Individuals who think that economic variables will change in a certain direction and will affect the financial investment instruments in a certain direction determine the ideal instrument to invest in.

Economic factors

Economic factors affecting financial investment instruments can be categorized under several headings (Albeni and Demir 2011; Şimşek 2004; Toraman et al. 2011; Topçu 2010; Öztürk 2011):

- Gold prices: Changes in gold prices have an impact on financial investment instruments since gold is an investment instrument itself. For example, individuals who anticipate an increase in gold prices and want to increase their profits invest their savings in gold; the demand and therefore the price of gold increases. The increase in gold prices attracts the attention of other investors who then shift their investments to gold (or vice versa). Therefore, it can be said that the changes in gold prices affect all other investment instruments.
- Stock index: Equity securities are securities issued by joint-stock companies and represent the share of participation in a given partnership capital (Öztürk 2011). Changes in the value of the stock provide information on the overall performance of the company. Stock indexes are a general indicator of stock markets; therefore, it can be said that they provide information about the general economic situation in the country (Albeni and Demir 2011). Stock movements and stock exchange operations in Turkey are carried out by Borsa İstanbul. Bist100 index has been formed to

observe the performance of 100 shares with the highest market value and transaction volume in Borsa İstanbul markets, and is used as the basic index for Borsa İstanbul.

- The terms of trade and import-export rates: Foreign trade is an important factor affecting exchange rates since the system serves trading with other countries. An importing country requires the currency of the exporting country (or a common currency) to make payments to the exporting country. Therefore, the demand for the exporting country currency (or the common currency) will increase, and simultaneously increase its relative value. The opposite case is valid for the exporting country. As a result of the direct effect of foreign trade on exchange rates, other investment instruments are affected indirectly.

- Foreign direct investments: Investment areas for growing companies in globalizing economies are not limited to the country where the company is established. These large companies invest in different countries due to various reasons (wages and tax differences, distance to resources, etc.). Consequently, the economic factors in the country and the values of financial investment instruments change. The foreign exchange rates and gold prices will be affected negatively in case of an increase in direct investments.

- Exchange rates: Since the cost of imported goods will increase as a result of the increase in exchange rates, it is expected to result in an increase in inflation and a decrease in import. Therefore, decrease in purchasing power and, consequently, changes in demand for investment instruments will be observed.

- Inflation: The relative increase in inflation in a country compared to the rest of the world causes a decrease in the purchasing power of the country's currency and an economic uncertainty in the country. This leads to the loss of credibility of the currency. In such a case, investors prefer to invest their savings in different methods (foreign currencies, precious metals, etc.) instead of national currency. In the reverse case, since the currency of the country does not lose value, individuals may choose to keep their capital in liquid form instead of investing.

- Interest rates: Changes in interest rates affect the investment decisions of individuals by changing their demand for goods and services and aggregating investment spending. In case of an increase in interest rates, individuals who want to make more profit from interest rates decrease their spending as well as their savings. In this way, they plan to get more returns.

- Unemployment rate: Savings will reduce when the purchasing power decreases as the unemployment rate in the country increases. Therefore, the investment opportunities will decrease, and the prices of the investment instruments will decrease. For example, due to the decrease in demand for imported goods, exchange rates will be negatively affected, and their profitability will be reduced.

- Balance of payments: A balance of payments deficit means that the country imports more goods, services, and capital than it exports. If such deficit exists, to achieve the balance the country needs to import financial capital, leading to an increase in foreign exchange rates. The change in exchange rates also causes other financial investment instruments' value to change.

- Money supply: The expansion in money supply will trigger inflation, which will result in a decrease in purchasing power, changing the demand for financial investment instruments.
- Oil prices: The change in oil prices, which is the most used energy source today, has a direct impact on the economies of countries. An increase in oil prices leads to an increase in production costs. This indirectly leads to increased inflation and reduced purchasing power. Changes in oil prices will affect the demand and profitability of financial investment instruments.
- Economic growth: There are two fundamental views of economic growth: consumption-based and production-based. If economic growth is based on consumption, the long-term consumption will increase the inflation and imports. While the increase in inflation decreases the purchasing power, the increase in imports will lead to an increase in foreign exchange rates. In a production-based growth, the increase in long-term production will lead to a decrease in domestic costs and thus resulting in a decrease in inflation and imports. In both types of growth, the profitability ratios of financial investment instruments will change.

Therefore, financial investment instruments can be directly or indirectly affected by each other and by many other economic factors. As the direction and severity of these interactions vary, their duration of impact also varies. The profitability of the investment is affected by this situation. Thus, it is important to be cognizant about these interactions when making a decision for financial investment.

Literature review

Several studies discuss the factors affecting the returns of the different financial investment instruments. These studies generally select gold and exchange rate as financial investment instruments and analyze different time periods and variables. Results vary according to variables and the countries. This section summarizes some of the studies in the literature.

Topçu (2010) aimed to determine the factors affecting the gold prices. He used the monthly data of gold prices, Dow Jones Industrial Index, US real interest rate, dollar/world exchange rate, oil prices and US inflation rate, and global monetary supply during the period 1995:01–2009:09. According to the results, Dow Jones Industrial Index and dollar/world exchange rate affect gold prices negatively and global monetary supply affects gold prices positively. Moreover, financial crisis influences gold prices positively, as expected. Toraman et al. (2011) aimed to determine the factors affecting gold prices. They used the monthly data of gold prices, oil prices, dollar index, Dow Jones Industrial Index, US real interest rate, and US inflation rate variables during the period 1992:01–2010:03. According to the results, the highest correlation found is between gold prices and dollar index, which is negative. A positive correlation is found between gold prices and oil prices. Toraman et al. (2011) concluded that gold returns do not show linear changes during the analysis period, that is, markets are not linear. Karataş and Ürkmez (2013) examined the dynamics affecting gold prices during global crisis. They used monthly data of Dow Jones Index, petrol prices, silver prices, and gold prices during the period 2007:01–2013:02. They conducted the Johansen co-integration test, vector error correction model (VECM) analyses, and checked impulse response functions.

According to the results of the co-integration test, there is a long-term relationship between the variables. Results of the impulse response functions show that petrol prices affect gold prices more than other indicators. They revealed that gold prices unsurprisingly increase during crisis periods and are influenced by the indicators.

Şimşek (2004) conducted an ARDL bound test to determine the factors that influence the Turkish real exchange rate in the long run. He used the annual data of real exchange rate, net foreign capital inflows, income difference between Turkey and a weighted average of major trading partners, money supply, terms of trade, and trade balance during the period 1975–2003. The results show that net foreign assets, income difference between Turkey and a weighted average of major trading partners, M2 money supply, trade balance, and terms of trade influence the real exchange rate in Turkey. Twarowska and Kakol (2014) examined the factors affecting the fluctuations in the EUR/PLN (Euro/Polish Zloty) exchange rate. They used a linear regression function to the annual data of average EUR/PLN exchange rate, the difference between the rate of gross domestic product (GDP) growth in Poland and in the euro area, the difference between inflation rate in Poland and in the euro area (HICP), the difference between money market interest rates (day-to-day) in Poland and in the euro area, current account balance in Poland, financial account balance in Poland, and the difference between government deficit as % GDP in Poland and in the euro area during the period 2000–2013. The results of the study show that the fluctuations were caused by GDP, HICP, current account balance, financial account balance, and government deficit. The results confirm that a relative increase in the price level and faster economic growth in Poland compared to the euro area caused the zloty depreciation.

This literature review shows that only one investment instrument is selected, and the factors affecting it are examined. There are no studies examining the different investment instruments. This study makes a unique contribution to the literature since it examines which of the different investment instruments are more profitable. Moreover, it will serve as a guide to investors as to which investment instrument will be the most profitable depending on investors' choices.

Data and application

As mentioned before, we selected EURO, gold (GOLD), and USD as the financial investment instruments. As for the economic factors that could affect the selected financial investment instruments, we used Bist100 index (BIST), current account balance (CAB), consumer price index (CPI), export/import ratio (EI), foreign direct investment (FDI), industrial production index (IPI), oil prices (OP), and terms of trade (TOT). We could not use all the factors mentioned in Section 2 because of lack of data. Opportunities have decreased in financial markets that have been troubled by the 2008–2009 financial crisis. After the crisis period, as the markets began to recover, people started to evaluate their savings by investing. For the crisis to not affect the analysis results, the analysis period was chosen between the post-crisis period and the date where the most appropriate data was available at the time of the study. Therefore, the selected variables belong to the period 2009:01–2018:05, and the data were obtained from CBRT and TURKSTAT databanks. Figure 2 shows the graphs of variables.

Since monthly data was used, all variables were seasonally adjusted by using the Census X-13 method to avoid the seasonality problem.

Fig. 2 Data
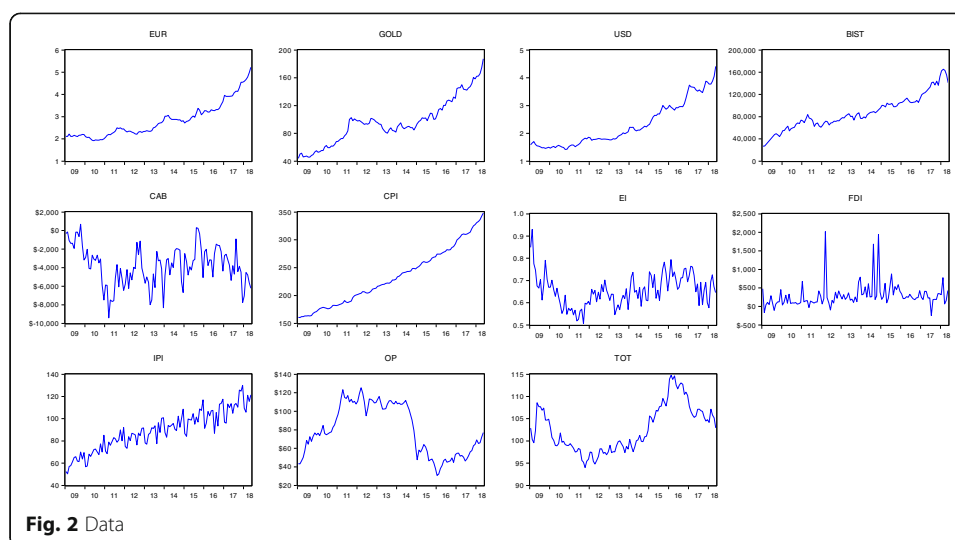
Econometrical model

In econometric analysis, the spurious regression problem might occur if the variables are not stationary. In the event of spurious regression, the results may not reflect the reality. Therefore, it is important to investigate whether the variables are stationary before the analysis. Several conventional unit root tests are available to investigate stationarity; the most commonly used is the augmented Dickey-Fuller (ADF) unit root test. However, the ADF unit root test does not take structural breaks of the time series into account. According to Perron (1989), estimations would provide deviant results in the existence of structural breaks (Sun et al. 2017). Since political and economic events can cause the time series to change their structure, the ADF unit root test result might not be reliable for our data. To ensure reliable unit root test results, we used the Breakpoint unit root test as well. Tables 1 and 2 show the results of the ADF and Breakpoint unit root tests of the data in the analysis.

According to results of the unit root tests, some of the variables are I(0), the rest are I(1) and none of them is I(2). Since the stationarity of the variables is examined, we can begin to check the relation between the series. In order to do that, we need to conduct a co-integration test.

Co-integration test

In econometric analysis, there are several co-integration tests to analyze the relationship between series. If all the series used are stationary, the conventional ordinary least squares method is used. If the series is not stationary at the level but all of them are first degree integrated (i.e., I (1)), the Engle and Granger (1987) or Johansen (1991) methods are used. If the series used are not integrated at the same level (i.e., if not all of the variables in the analysis are I (1)) then these two methods will give deviant results. Therefore, these two methods are not applicable if the series are not integrated at same level. However, in cases where the series are integrated at different degrees, the co-integration relation between variables can be estimated with the ARDL approach (Pesaran and Shin 1999; Pesaran et al. 2001; Türkay and Demirbaş 2012). The ARDL

Table 1 ADF unit root test results

Variables	Constant		Constant, Linear Trend		None	
	t-Statistic	Probability	t-Statistic	Probability	t-Statistic	Probability
EURO	1.6497	0.9995	−1.1188	0.9206	3.0123	0.9993
D (EURO)	−8.1244[b]	0.0000	−8.5353[b]	0.0000	−7.4696[b]	0.0000
GOLD	−0.6514	0.8534	−1.5461	0.8076	3.6551	0.9999
D (GOLD)	−9.1455[b]	0.0000	− 9.0867[b]	0.0000	−8.4213[b]	0.0000
USD	1.3179	0.9986	−2.5807	0.2899	2.7812	0.9986
D (USD)	−7.2914[b]	0.0000	−7.6634[b]	0.0000	−6.7263[b]	0.0000
BIST	−3.4182[a]	0.0123	−4.3973[b]	0.0033	3.1834	0.9996
CAB	−8.3867[b]	0.0000	−8.3639[b]	0.0000	−0.5608	0.4721
CPI	1.9008	0.9998	−0.9177	0.9496	13.946	1.0000
D (CPI)	−9.0205[b]	0.0000	−9.1779[b]	0.0000	−0.7444	0.3917
FDI	−3.1539[a]	0.0256	−4.5544[b]	0.0020	−0.8757	0.3345
D (FDI)	−10.0208[b]	0.0000	− 10.2301[b]	0.0000	0.0644	0.7012
IPI	−0.9465	0.7698	−4.7263[b]	0.0011	3.7500	0.9999
D (IPI)	−10.0992[b]	0.0000	− 10.0739[b]	0.0000	− 12.6901[b]	0.0000
OP	−1.6078	0.4752	−2.4246	0.3650	0.5031	0.8227
D (OP)	−8.9079[b]	0.0000	−8.9791[b]	0.0000	− 8.9204[b]	0.0000
TOT	−1.2494	0.6509	−1.5020	0.8233	0.0238	0.6883
D (TOT)	−9.3223[b]	0.0000	−9.2712[b]	0.0000	− 9.3620[b]	0.0000

[a], [b] indicates significance at %5 and %1 level, respectively

boundary test approach provides a great advantage in the analysis of integrated series of different degrees.

Since the variables considered are all I(0) or I(1), the ARDL bounds test is chosen to check the effects of the economic variables on the financial investment instruments (EURO, GOLD, and USD). Before obtaining the results from the ARDL test, the presence of the long-term relationship between the series should be examined by the bounds test. The null hypothesis (H$_0$) of the ARDL bounds test is that here is no long-term relationship between the variables. If the value of the F-statistic calculated by the ARDL bounds test is greater than the upper limit value of the significance level; the null hypothesis is rejected at the corresponding significance level. However, if the value of the F-statistic is smaller than the lower limit value, the null hypothesis cannot be rejected. If the calculated F-statistic falls between the limit values, a decision cannot be made at the corresponding significance level. Table 3 shows the bounds test results of the three different models.

As seen in the table, the F-statistic of all three models is greater than the upper limit of the corresponding 1% significance level. This shows that the null hypothesis of the bounds test for all models can be rejected, meaning that there are long-term relationships for each model.

ARDL model and long-term form
The lag lengths for the ARDL model have been determined automatically according to the Akaike information criteria (AIC). Since the series used in the analysis is monthly,

Table 2 Breakpoint unit root test results

Trend Specification	Intercept only			Trend and intercept								
Break Specification	Intercept only			Intercept only			Trend and intercept			Trend only		
	t-Statistic	Prob.	Break Date	t-Statistic	Prob.	Break Date	t-Statistic	Prob.	Break Date	t-Statistic	Prob.	Break Date
EURO	−0.3290	> 0.99	2016 M10	−2.5494	0.9809	2016 M10	−2.9090	0.9727	2015 M09	−2.8470	0.7793	2016 M07
D (EURO)	−8.8550[b]	< 0.01	2015 M11	−9.0452[b]	< 0.01	2014 M01	−9.2254[b]	< 0.01	2015 M09	−8.6934[b]	< 0.01	2018 M02
GOLD	−2.2811	0.9498	2015 M12	−3.4865	0.7002	2012 M12	−3.0549	0.9541	2012 M11	−1.9398	> 0.99	2015 M12
D (GOLD)	−10.5885[b]	< 0.01	2011 M08	−11.4543[b]	< 0.01	2011 M08	−11.6370[b]	< 0.01	2011 M08	−9.4209[b]	< 0.01	2018 M04
USD	−0.5954	> 0.99	2015 M01	−3.6670	0.5859	2015 M01	−4.4301	0.2702	2015 M01	−4.3169	0.0867	2013 M04
D (USD)	−8.1463[b]	< 0.01	2018 M03	−8.3225[b]	< 0.01	2018 M04	−8.9835[b]	< 0.01	2017 M11	−8.3886[b]	< 0.01	2018 M03
BIST	−4.6665[a]	0.0272	2014 M04	−5.0509	0.0284	2009 M04	−4.6335	0.1801	2011 M05	−5.0360[a]	0.0114	2009 M06
CAB	−11.7756[b]	< 0.01	2011 M03	−10.6465[b]	< 0.01	2011 M03	−11.0613[b]	< 0.01	2011 M03	−9.5589[b]	< 0.01	2011 M04
CPI	−0.0567	> 0.99	2016 M05	−3.4391	0.7284	2016 M11	−4.5932	0.1959	2016 M11	−4.5309[a]	0.0493	2016 M09
D (CPI)	−9.7278[b]	< 0.01	2011 M05	−9.8994[b]	< 0.01	2011 M05	−10.0987[b]	< 0.01	2011 M05	−9.4852[b]	< 0.01	2018 M03
FDI	−5.0862[b]	< 0.01	2014 M11	−5.6847[b]	< 0.01	2009 M11	−5.8871[b]	< 0.01	2010 M03	−5.6889[b]	< 0.01	2010 M03
D (FDI)	−14.7558[b]	< 0.01	2017 M07	−17.1698[b]	< 0.01	2017 M07	−15.7627[b]	< 0.01	2017 M07	−11.4282[b]	< 0.01	2014 M12
IPI	−2.3688	0.9334	2016 M08	−11.5692[b]	< 0.01	2010 M02	−11.5900[b]	< 0.01	2010 M03	−11.1576[b]	< 0.01	2010 M03
OP	−3.9062	0.1911	2014 M08	−4.5462	0.1168	2014 M08	−3.3823	0.8651	2014 M09	−2.7085	0.8438	2017 M07
D (OP)	−9.9698[b]	< 0.01	2015 M01	−11.1216[b]	< 0.01	2016 M01	−11.0106[b]	< 0.01	2016 M01	−9.9642[b]	< 0.01	2015 M01
TOT	−3.1056	0.8778	2014 M09	−2.7460	0.8120	2014 M09	−2.7617	0.9853	2014 M11	−2.3845	0.9450	2010 M03
D (TOT)	−10.6107[b]	< 0.01	2009 M05	−10.6069[b]	< 0.01	2009 M05	−10.1253[b]	< 0.01	2016 M01	−9.6587[b]	< 0.01	2009 M11

[a], [b] indicates significance at %5 and %1 level, respectively

Table 3 Bounds test results

H₀: No levels relationship					
Dependent Variable	F-statistic	Degree of Freedom	Significance level	I (0)	I (1)
EURO	7.0319	9	1%	2.5	3.68
GOLD	8.9254	9	1%	2.65	3.97
USD	7.5707	9	1%	2.97	4.24

the maximum lag length is chosen as six, and according to the AIC the models are determined as ARDL (6, 6, 1, 3, 2, 3, 6, 2, 5, 3) for EURO, ARDL (2, 5, 1, 6, 2, 6, 4, 2, 6, 4) for Gold, and ARDL (2, 2, 5, 0, 6, 5, 6, 0, 0, 0) for USD. Table 4 shows the results of each estimation.

According to the ARDL model co-integration and long-term form results, the coefficients of error correction model (ECM) are negative and significant. The ECM coefficients are found to be (− 0.644034), (− 0.242021), and (− 0.381617), which shows that if there is a short-term deviation in the variables the system will return to long-term equilibrium again in about 2 months for EURO, 4 months for Gold, and 3 months for USD.

We checked the stability of the coefficients of the long-term models using the cumulative sum (CUSUM) of recursive residuals and the CUSUM of square (CUSUMSQ) stability tests. Figure 3 shows the results of the tests.

As seen in the figures, since the plot of the CUSUM and CUSUMSQ tests for all three models falls inside the 5% significance critical bounds, we can assume that the coefficients are stable. Therefore, we can use statistically significant coefficients for the decision-making problem of financial investments.

Decision making

Humans are often faced with situations in everyday life where they are required to make decisions. In some cases, this process is faster and, in others, it is slower. However, sometimes, it can be rather challenging to make a decision. The reason for this difficulty is the complexity and availability of options. This study attempts to simplify this process by using various mathematical instruments.

Fuzzy sets

Fuzzy sets are among the most frequently used mathematical methods in decision-making problems. The fuzzy set definitions that are used in this study are given below.

Definition 1 *Let $X \neq$ be a set and $I = [0, 1]$ be a closed interval. Let I^X be the set of all transformations defined from X to I, each element of I^X is called a fuzzy set in X* (Zadeh, 1965).

In this study, symbols such as *A, B, ...* will be used to indicate fuzzy sets.

A fuzzy set *A* defined in *X* can be shown as a set of sequential pairs in the form of $A = \{(x, \mu_A(x)) : x \in X\}$ or as $A = \{x^{\mu_A(x)} : x \in X\}$. Here, the $\mu_A : X \rightarrow [0, 1]$ function is called the membership function of *A*, and the number of $\mu_A(x)$ is the membership degree of the element *x* of fuzzy set *A*. Elements with zero membership value are not usually displayed in the set.

Table 4 ARDL model and long-term form results

Dependent Variable: EURO ARDL (6, 6, 1, 3, 2, 3, 6, 2, 5, 3)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
ECM	-0.6440	0.0677	-9.4996	0.0000
$EUR = (1.3323)USD + (0.0041)IPI + (-0.2555)GOLD + (-0.0232)FDI + (-0.6808)EI + (0.0178)TOT$ $+ (-0.4949)CPI + (0.0063)CAB + (0.4214)OP + (0.3223) + ECM$				
Long-run Form				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
USD	1.3322*	0.0658	20.2411	0.0000
IPI	0.0040*	0.0012	3.3216	0.0015
GOLD	-0.2554*	0.0251	-10.1638	0.0000
FDI	-0.0232*	0.0076	-3.0574	0.0033
EI	-0.6808*	0.1182	-5.7609	0.0000
TOT	0.0177*	0.0024	7.2870	0.0000
CPI	-0.4949*	0.1087	-4.5531	0.0000
CAB	0.0062	0.0112	0.5634	0.5752
OP	0.4213*	0.0340	12.3923	0.0000
C	0.3223	0.5117	0.6299	0.5312
$R^2 = 0.849782$ $\bar{R}^2 = 0.772527$				
Dependent Variable: GOLD ARDL (2, 5, 1, 6, 2, 6, 4, 2, 6, 4)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
ECM	-0.2420	0.0238	-10.1424	0.0000
$GOLD = (-1.3909)EUR + (0.0059)IPI + (2.4587)USD + (-0.0951)FDI + (2.7329)EI + (1.1872)BIST$ $+ (-2.4364)CPI + (-0.2431)CAB + (0.4445)OP + ECM$				
Long-run Form				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
EURO	-1.3908*	0.3016	-4.6115	0.0000
IPI	0.0058	0.0048	1.2339	0.2221
USD	2.4586*	0.3957	6.2141	0.0000
FDI	-0.0951*	0.0306	-3.1049	0.0029
EI	2.7328*	0.7624	3.5847	0.0007
BIST	1.1872*	0.3126	3.7976	0.0003
CPI	-2.4364*	0.7234	-3.3679	0.0013
CAB	-0.2431*	0.0462	-5.2568	0.0000
OP	0.4444*	0.0771	5.7663	0.0000
$R^2 = 0.832963$ $\bar{R}^2 = 0.739619$				
Dependent Variable: USD ARDL (2, 2, 5, 0, 6, 5, 6, 0, 0, 0)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
ECM	-0.3816	0.0412	-9.2434	0.0000
$USD = (0.6510)EUR + (-0.0187)IPI + (0.2727)GOLD + (0.0737)FDI + (-0.6314)EI + (-0.0042)TOT$ $+ (1.6113)CPI + (0.0058)CAB + (-0.2212)OP + ECM$				
Long-run Form				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
EURO	0.6510*	0.1206	5.3962	0.0000
IPI	-0.0186*	0.0061	-3.0462	0.0033
GOLD	0.2726*	0.0591	4.6120	0.0000
FDI	0.0736**	0.0290	2.5438	0.0132
EI	-0.6313**	0.2886	-2.1878	0.0320
TOT	-0.0041	0.0035	-1.1768	0.2433
CPI	1.6112*	0.6029	2.6725	0.0094
CAB	0.0058	0.0065	0.8930	0.3749
OP	-0.2211*	0.0422	-5.2414	0.0000
$R^2 = 0.797927$ $\bar{R}^2 = 0.728864$				

**, * indicates significance at %5 and %1 level, respectively.

If an L complete lattice is considered in place of the [0,1] set, an A is called lattice fuzzy (L-fuzzy) set on X and defined as (Goguen 1967):

$$A : X \rightarrow L$$

Here, the L complete lattice is the value set of A. L^X consists of all functions defined from X to L and is called L-fuzzy space.

Definition 2 *Let $(L, \leq)$ be a partially ordered set and $A, B \in L^X$ (Goguen 1967).*

(1) If $\mu_A(x) \leq \mu_B(x)$ for each $x \in X$, A is called the fuzzy subset B and is indicated by $A \leq B$.

Fig. 3 a: EURO. **b**: Gold. **c**: USD
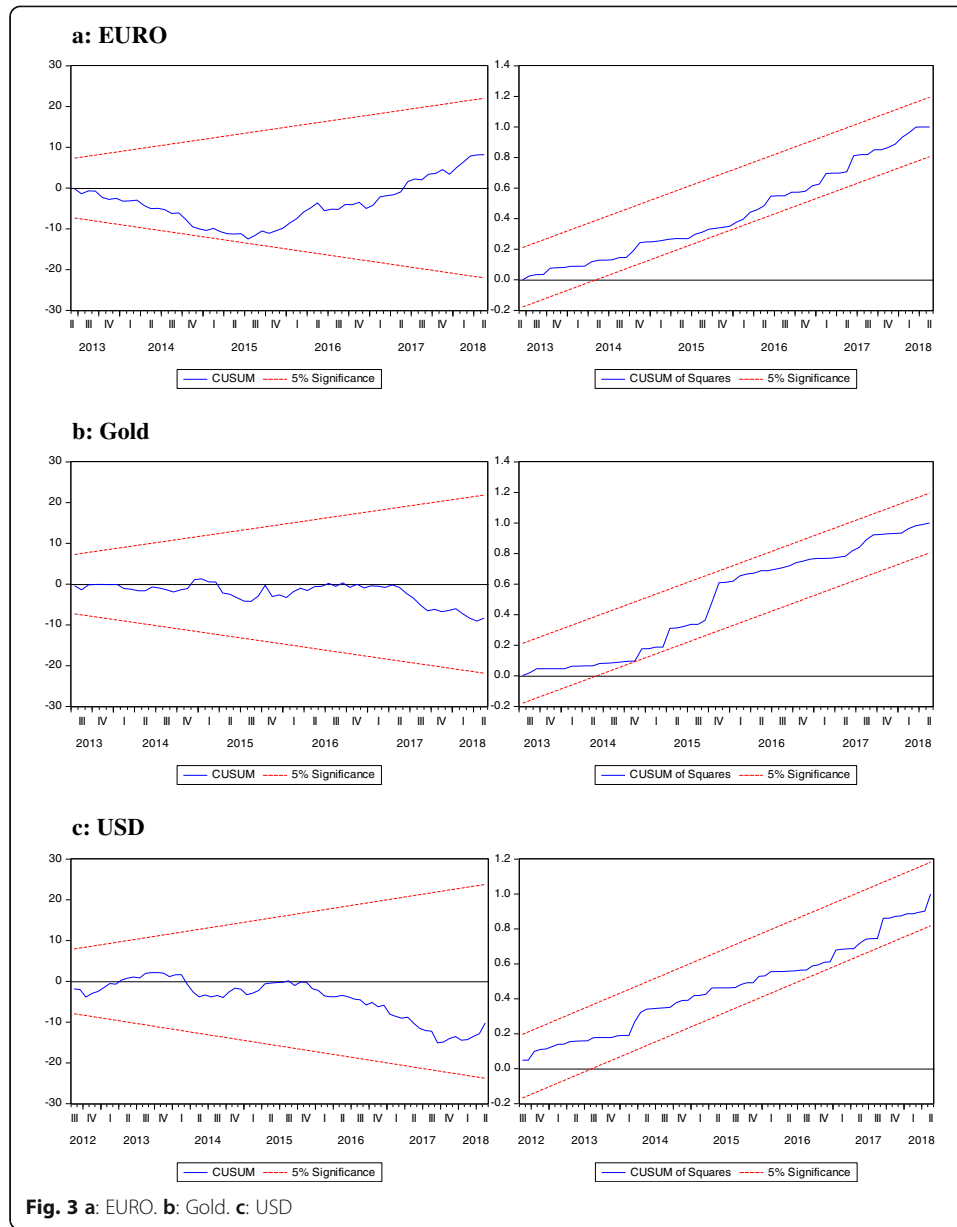
(2) If $\mu_A(x) = \mu_B(x)$ for each $x \in X$, fuzzy sets A and B are called equals and indicated by $A = B$.

(3) For each X, the fuzzy set C, whose membership function is defined as $\mu_C(x) = \max\{\mu_A(x), \mu_B(x)\}$, is called the combination of the fuzzy sets A and B and is indicated with $C = A \vee B$.

(4) For each X, the fuzzy set C, whose membership function is defined as $\mu_C(x) = \min\{\mu_A(x), \mu_B(x)\}$, is called the intersection of the fuzzy sets A and B and is indicated with $C = A \wedge B$.

Definition 3 *Let* $L \subset \mathbb{R}$ *and* $A \in L^X$. *In this case,* $A^\alpha = \{(x, \mu_{A^\alpha}(x)) : x \in A\}$ *and the membership function* $\mu_{A^\alpha}(x) : X \to L$ *is defined as*

$$\mu_{A^\alpha}(x) = \begin{cases} (\mu_A(x))^\alpha & , \mu_A(x) \geq 0 \\ -(|\mu_A(x)|)^\alpha & , \mu_A(x) < 0 \end{cases}$$

The Bellman and Zadeh (1970) method, also known as the max-min method, was the first to use fuzzy sets in decision making. Various decision-making methods were then proposed by the researchers using fuzzy sets. One of these methods is AHP.

Analytic hierarchy process

AHP was first described by Saaty in 1977. In this method, the important relationship between the sets of options for a multi-criteria decision is determined by analytical methods. The method used to reach the decision with AHP is summarized as follows:

- Step 1: Defining the Decision-Making Problem: For a decision-making problem, m decision points (alternatives) and n factors (criteria) affecting these decision points are determined and a hierarchical structure is formed. Comparisons or evaluations that provide numerical representation of the relative importance between the criteria and decision points are then calculated, as shown in Table 5.
- Step 2: Determining the Binary Comparison Matrix: For a decision-making problem with n number of criteria, the nxn dimensional binary comparison matrix (A matrix) for the criteria is created.

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$$

By consulting with experts, the importance levels of the criteria compared to each other are determined and converted to numerical values according to the scale in Table 5. This matrix contains the values indicating how important the ith row element is relative to the jth column element. The following relationship exists between the elements of this matrix in which the diagonal elements are equal to 1.

$$a_{ij} = \frac{1}{a_{ji}}$$

- Step 3: Determining the Normalized Binary Comparison Matrix: A normalized binary comparison matrix is generated by dividing each value in the binary

Table 5 Binary comparison scale

Value Definitions	Importance values
Both criteria have equal importance	1
The 2nd criterion is moderately less important than the 1st criterion	3
The 2nd criterion is strongly less important than the 1st criterion	5
The 2nd criterion is very strong less important than the 1st criterion	7
The 2nd criterion is extremely less important than the 1st criterion	9
Intermediate more important	2,4,6,8

comparison matrix by the total value of the column it belongs to. Thus, the jth column vector $(j = 1...n)$,

$$B_j = \begin{bmatrix} b_{1j} \\ b_{2j} \\ \vdots \\ b_{nj} \end{bmatrix}$$

is created by using the formula,

$$b_{ij} = \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}}$$

Then, by using the nth column vector, the normalized binary comparison matrix is formed as:

$$B = \begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1n} \\ b_{21} & b_{22} & \cdots & b_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ b_{n1} & b_{n2} & \cdots & b_{nn} \end{bmatrix}$$

- Step 4: Calculation of Relative Weights for Different Purposes: At each level of the decision hierarchy, the element with the highest score is more important. To choose from among alternatives, the relative compound weight of each element at the last level should be calculated. The weight of each criterion is calculated by taking the arithmetic mean of the row elements of the normalized binary comparison matrix. Thus, by using the formula,

$$w_i = \frac{\sum_{k=1}^{n} b_{ik}}{n}$$

The weight of each criterion (w_i) is calculated, and by using these values, the weight matrix (W) is obtained as:

$$W = \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix}$$

Since the weight matrix has been obtained, the decision-making algorithm can now be developed to decide the most suitable one among the alternatives.

Decision-making algorithm

The decision-making algorithm we used in this study has been developed through the following steps:

Step 1. The appropriate variables for the problem are determined and their data is collected. The effect of these variables on each other and the effect rate is then be obtained by appropriate methods and analyses.

Step 2. The data obtained in the first step is written as L-fuzzy set.

Step 3. The priority of the decision maker for L-fuzzy sets and the weights of L-fuzzy sets are determined by using AHP.

Step 4. The membership values of the alternatives in the D decision set are determined by one of the following methods according to the risk attitude of the decision maker, and a decision set is then created.

a) (Max-Max): If the investor is a risk-prone decision-maker, the membership value of the alternative can be calculated by taking the maximum of the membership values of the alternatives in the L-fuzzy sets.

b) (Lagrange): If the investor is prone to average risk, the membership value of the alternative can be calculated by calculating the arithmetic mean of the membership values of the alternatives in the L-fuzzy sets.

c) (Min-Max): If the investor is a risk-prone decision-maker, the membership value of the alternative can be calculated by taking the minimum of the membership values of the alternatives in the L-fuzzy sets.

Step 5. The alternative with the highest membership value in the decision set is then selected.

An application of decision making for financial investment

Example 1. *Ahmet wants to decide the appropriate investment instrument among Gold, EURO, and USD. As a follower of behavioral finance, he believes the past movements of these investment instruments and the factors affecting them will help him make a decision. He believes he can predict the future returns of these by analyzing their past prices. He considers the movements of these investment instruments in the last month, the last 3 months, the last 6 months, the last 12 months, and all times. He is an investor who wants to take average risk. Now, let us help Ahmet choose the most appropriate investment instrument by following the decision steps.*

Step 1. We obtained the variables and data from the econometrical analysis provided in Section 4.1. We multiplied the statistically significant coefficients obtained from the ARDL model and the average growth of each variable in the respective period (last month, last 3 months, etc.).

Step 2. By using the data from step 1, we created the L-fuzzy sets for each considered period (i.e., C_1 is the L-fuzzy set for growth in the last month, and so on).

$$C_1 = \{g^{0.2578}, d^{0.4580}, e^{-0.010}\}$$
$$C_3 = \{g^{0.0794}, d^{-0.0108}, e^{-0.0067}\}$$
$$C_6 = \{g^{0.0382}, d^{0.0130}, e^{-0.0308}\}$$
$$C_{12} = \{g^{0.0801}, d^{0.0156}, e^{-0.0345}\}$$
$$C_T = \{g^{0.0687}, d^{0.0113}, e^{0.0181}\}$$

Here, d denotes the USD exchange rate, e denotes the EURO exchange rate, and g denotes Gold prices.

Step 3. Ahmet's priority regarding the L-fuzzy sets is given below:

- The growth in the last month and the average growth in the last 3 months have equal importance.
- The growth in the last month is moderately less important than the average growth in the last 6 months.
- The growth in the last month is significantly less important than the average growth in the last 12 months.
- The growth in the last month is significantly less important than the average growth at all times.
- The average growth in the last 3 months is moderately less important than the average growth in the last 6 months.
- The average growth in the last 3 months is significantly less important than the average growth in the last 12 months.
- The average growth in the last 3 months is significantly less important than the average growth at all times.
- The average growth in the last 6 months is significantly less important than the average growth in the last 12 months.
- The average growth in the last 6 months is moderately less important than the average growth at all times.
- The average growth in the last 3 months is significantly less important than the average growth at all times.
- The average growth in the last 12 months is moderately more important than the average growth at all times.

Using Ahmet's priority, the binary comparison matrix A is created as:

$$A = \begin{bmatrix} 1 & 1 & 3 & 7 & 5 \\ 1 & 1 & 3 & 7 & 5 \\ \frac{1}{3} & \frac{1}{3} & 1 & 5 & 3 \\ \frac{1}{7} & \frac{1}{7} & \frac{1}{5} & 1 & \frac{1}{3} \\ \frac{1}{5} & \frac{1}{5} & \frac{1}{3} & 3 & 1 \end{bmatrix}$$

Using AHP, we calculated the B matrix and the weight matrix of L-fuzzy sets (W) as:

$$B = \begin{bmatrix} 0.3737 & 0.3737 & 0.3982 & 0.3043 & 0.3488 \\ 0.3727 & 0.3737 & 0.3982 & 0.3043 & 0.3488 \\ 0.1245 & 0.1245 & 0.1327 & 0.2174 & 0.2093 \\ 0.0534 & 0.0534 & 0.0265 & 0.0435 & 0.2093 \\ 0.0747 & 0.0747 & 0.0442 & 0.1304 & 0.0698 \end{bmatrix}$$

$$W = \begin{bmatrix} 0.3597 \\ 0.3597 \\ 0.1617 \\ 0.0400 \\ 0.0788 \end{bmatrix}$$

Using the weight matrix, the weights α_1, α_3, α_6, α_{12}, and α_T are 0.3597, 0.3597, 0.1617, 0.0400, and 0.0788, respectively. We obtained the L-fuzzy sets according to these weights as:

$$C_1^{a_1} = \left\{ g^{-0.4112}, d^{0.3678}, e^{0.4394} \right\}$$
$$C_3^{\alpha_3} = \left\{ g^{-0.0963}, d^{0.2874}, e^{0.3796} \right\}$$
$$C_6^{a_6} = \left\{ g^{0.3881}, d^{0.5144}, e^{0.5528} \right\}$$
$$C_{12}^{\alpha_{12}} = \left\{ g^{-0.8654}, d^{0.8877}, e^{0.7777} \right\}$$
$$C_T^{\alpha_T} = \left\{ g^{-0.6674}, d^{0.7021}, e^{0.7065} \right\}$$

- Step 4. Since Ahmet is a decision maker who wants to take an average risk, the decision set is obtained by the Laplace method.

$$D = \left\{ g^{\frac{(-0.4112)+(-0.0963)+(0.3881)+(-0.8654)+(-0.6674)}{5}}, d^{\frac{(0.3678)+(0.2874)+(0.5144)+(0.8877)+(0.7021)}{5}} \right.$$
$$\left. , e^{\frac{(0.4394)+(0.3796)+(0.5528)+(0.7777)+(0.7065)}{5}} \right\}$$
$$= \left\{ g^{-0.3304}, d^{0.5519}, e^{0.5712} \right\}$$

- Step 5. Consequently, according to Ahmet's choices, the most appropriate financial investment instrument is found to be EURO.

Conclusion

Keeping savings, which constitute the portion of income post consumption, idle can cause negative consequences for both the household and the national economy. Therefore, savings should be invested in appropriate investment instruments. When deciding on investment instruments, the past movements of these instruments and other factors affecting them should be taken into consideration. Our aim in this study is to create a mathematical model which helps people to find an appropriate investment instrument among others. An application has been added both to check the applicability of the model created and to help investors in Turkey decide which financial investment instrument to invest in. In this application, we chose the most common investment instruments in Turkey, which are EURO, gold, and USD. With the help of the model, which we have obtained by considering the factors affecting the financial investment instruments and the preferences of the investor, we concluded that the most suitable instrument for financial investment is EURO.

The limitation of this study is that data and factors besides economic data could not be included in the analysis since they were lacking. Therefore, we concluded the analysis with the most up-to-date data set that we could acquire at the time of the study. If this study is to be expanded, a more general investment portfolio can be created by using different investment instruments (copper, silver, other securities, etc.). In addition, by changing the frequency of data (i.e., using daily or weekly data), if available, more accurate results can be obtained from econometric analysis, which can positively affect the accuracy of the mathematical model. Since the investor in the model has a large impact on the decision and the decisions of the investor may vary, it is important to take into account the preferences of investors with different tendencies.

Ahmet Karadaş. Serkan Atmaca conducted the mathematical modelling for the coefficients obtained from ARDL model and interpreted the results. Both authors read and approved the final manuscript.

Availability of data and materials
The datasets used and/or analyzed during the current study were obtained from CBRT, TURKSTAT, and onlygold.com databanks and can be provided on reasonable request.
CBRT: https://evds2.tcmb.gov.tr/.
TURKSTAT: http://www.turkstat.gov.tr/PreTabloArama.do?metod=search&araType=vt.onlygold.com: http://onlygold.com/Info/Historical-Gold-Prices.asp.

Competing interests
The authors declare that they have no competing interests.

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