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Should the Loss-aversion Behavior be Significant for Central Bankers? Evidence from Behavioral Economics

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ABSTRACT

This paper compares the effectiveness of the monetary policy based on conventional utility function and prospect theory. According to prospect theory, in the face of uncertainty, people make decisions based on perceived losses and benefits, so they are more sensitive to losses than to gains of equal size. Achieving this goal, we estimated the DSGE Model for the Iranian economy. The results of Bayesian estimation showed that under prospect theory, the inclusion of the loss-aversion component affects the household consumption behavior, the labor supply, and the real money demand**.** Also, The results of the Impulse-Response analysis show that an expansionary monetary shock led to an overestimate of inflation expectations due to fear of losses resulting from rising inflation. Hence, under the prospect theory, inflation increases relatively more, and the interest rate decreases with less intensity. Moreover, the more attention to the behavior of loss-aversion agents by policymakers, the less volatility is in macroeconomic variables.

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1. Introduction

Today, paying attention to behavioral components plays an essential role in describing and predicting decision-making behaviors under uncertainty. There is a consensus that the prospect theory can achieve a good performance in judgment and decision-making under the circumstances of risk and uncertainty (Wang et al., 2020). Kahneman and Tversky (1979) argued choices among risky prospects are inconsistent with the basic tenets of utility theory. In this regard, agents are risk-averse over gains and risk-taking over losses, rather than being completely risk aversion, as assumes in the classical theory (Curatola, 2017). Particularly, agents exhibit the behavior of loss aversion, so losses are valued more than the equivalent gains. They are also more sensitive to losses than to gains of equal size. Hence, Kahneman and Tversky (1979) criticized the theory of expected utility as a descriptive model of decision-making under risk and developed an alternative model called the prospect theory. In general, the prospect theory has been successful in accurately describing the behavior of agents under uncertainty. In particular, people place less weight on merely probable outcomes in comparison with those obtained under certainty. This tendency, called the certainty effect, contributing to risk-aversion in choices involving sure gains and risk-taking in those concerning sure losses (Kahneman and Tversky, 1979). The risk-averse behaviors are conservative and prefer to achieve a sure return. Their utility function is concave, in which marginal utility decreases with increasing wealth. In contrast, the risk-taking utility function is convex and indicates diminishing marginal utility to increase wealth, so that they assign relatively less value to large losses. Loss-aversion and risk-taking behaviors are represented by the asymmetric s-shaped utility function, which is convex over losses, concave over gains, and generally steeper for losses than gains (Kahneman and Tversky, 1979).

In addition to loss aversion, reference dependence and diminishing sensitivity are considered as main behavioral characteristics in the prospect theory, that is the value of the loss or gain depends on the reference level, so the more it is away from the reference level, the more the amount of loss or gain diminishes. Therefore, studying risk-taking and risk-aversion behavior is essential to understand how people make decisions under uncertainty and also, has important implications in macroeconomic modeling.

The loss-aversion behavior has found widespread empirical and experimental support in the literature (Thaler et al., 1997; Santoro et al., 2014). However, little effort has been made to examine the effects of loss-aversion, a fundamental component of behavioral economics, on the impact of monetary policy on macroeconomic dynamics from the perspective of general equilibrium. The innovation of this study is the inclusion of the prospect theory in a dynamic stochastic general equilibrium. In this regard, using a dynamic stochastic general equilibrium model, we have evaluated two models; with the loss-aversion parameter and without it, and then we compared the effectiveness of monetary policy under these two models.

This study is organized as follows. Section 2 provides a review of the literature. Section3 describes a dynamic stochastic general equilibrium model. Section 4 discusses data and calibrated parameters and analyses the empirical evidence resulted from the model. Section 5 concludes the paper. Finally, the appendixes contain descriptions of the model and diagnostic test results of estimation accuracy.

2. Literature Review

Erfani (2003) argued the prospect theory of Kahneman and Tversky (1979) challenged economists' view of making economic decisions under the influence of self-interest motives and rational behavior. Additionally, classical theory is incomplete in describing real-world behavior. The evidence suggests that human judgment and decision-making in uncertain situations rely on shortcuts or certain mindsets that systematically deviate from the traditional utility theory.

Rosenblatt-Wisch (2008) introduced the prospect theory in a neoclassical growth model. The results showed that the higher the discount factor, the lower the loss-aversion. This result illustrates that the discount factor and the loss aversion coefficient are complementary. More specifically, these two have a direct relationship; the higher the discount factor or loss aversion coefficient, the more losses incurred in the future. Thus, by keeping the consumption path constant at a given level, two forces, namely, a higher loss-aversion coefficient and a higher discount factor at work, making future losses more crucial. Therefore, it is not surprising that *ceteris paribus*, by lowering one component, the other will have to increase to explain a given consumption path and vice versa. Also, the loss-aversion parameter increases as the updating horizon become longer. Tracing loss-aversion in aggregate data could have implications for macroeconomic modeling.

Dimmock and Kouwenberg (2010) experimentally examined how loss-aversion affects households' equity market participation and household portfolio choice. The results indicated loss-aversion is a fundamental feature of the household investment decision-making process. Consequently, households frame events as either gains or losses relative to a reference point and assign losses more weight than gains. Hence, higher loss-aversion is associated with a lower probability of households' equity market participation, and loss-averse households allocate significantly less of their wealth to equities relative to those with standard preferences.

Ashta and Otto (2011) stated the loss-aversion is the result of having a value function defined according to the status quo. The value function is positive and concave over gains and is negative, convex, and more steeply sloped over losses. The reference to the status quo indicates that individuals are more sensitive to reduction well-being (Benartzi and Thaler, 1995) or wealth (Thaler et al., 1997).

Ciccarone and Marchetti (2013) considered some factors of the prospect theory, such as reference dependence, diminishing sensitivity, and the loss-aversion into the agents' utility function. They stated that the presence of behavioral factors negatively affects the natural level of output. Also, loss-aversion leads to a reduction in output variance. They argued loss aversion's agents behaved in a precautionary manner, suggesting that the resources they bring to the next period may be affected by a monetary shock hitting the economy. Agents' psychological attitudes form a channel through which financial phenomena influence the economy's real side. The results revealed the expected utility under the loss-aversion is lower than that obtained in the absence of the loss-aversion.

Manzoor and Taheri (2014) argued the assumption of rational behavior is one of the most determining foundations of conventional economics and constitutes the presupposition of economic theories. Although this assumption provides a powerful analytical tool and simplifying human behavior, it ignores the complexities of human behavior and the ethical norms, which leads to analyzes and predictions that are not necessarily realistic. Hence, more attention to psychological considerations is necessary to achieve more realistic analyzes in economics.

Humpe and Macmillan (2014) investigated nonlinear behavior in stock markets. Based on the prospect theory of Kahneman and Tversky (1979), They emphasized that agents are loss averse. Also, an investor's utility function is dependent on gains and losses according to the different market states, and investor behavior may depend upon the movement of stock market returns, which means investors are less likely to trade when market returns are falling than rising.

Santoro et al. (2014) introduced the prospect theory in a stochastic dynamic general equilibrium model. They expressed that output response to a monetary tightening is more robust in contractions as compared with expansions. Also, despite the amplification of output responses, downward wage rigidity induced by loss-averse preferences tends to weaken inflation responses during negative growth cycles.

Ni et al. (2015), Inspired by the prospect theory, provided a logical explanation for asymmetric patterns. They argued investors evaluate the values of gains and losses concerning their specific reference point, and their utility functions are unbalanced over losses and gains.

Saghafi et al. (2015) predicted the trading behavior of investors in the stock market. They presented a model that emphasizes certain aspects of investors' behavioral bias, such as risk-aversion and loss-aversion. The results are consistent with the prospect theory so that the investor is more sensitive to losses than gains.

Ahrens et al. (2017) introduced a new partial equilibrium theory of price adjustment by incorporating reference-dependent preferences and loss-aversion into a standard model. They illustrated consumers are loss-averse, and evaluate prices relative to reference prices that depend on rational price expectations from the recent past. Also, the loss-aversion obtained the price elasticity of demand in the loss to that over the gain domain leads to price stickiness. Implicitly, the demand responses for price increases are more elastic than price reductions. Accordingly, firms face a demand curve with a downward slope that kinked at the reference price. Firms change prices immediately in response to the permanent shocks, while consumers update their reference prices in the following period. To conclude, as prices rise, the demand curve shifts outwards, which is initiated by an upward adjustment in the reference price, increasing the long-run profit. In contrast, as prices fall, the demand curve shifts inwards, which is initiated by a downward adjustment of the reference price, reduces firms' long-term profit.

Curatola (2017), with the introduction of loss-aversion in standard portfolio choice models, analyzed the consumption-investment problem of a loss-averse investor. The results showed time variation in the reference level creates a link between past consumption gains or losses and the current portfolio choice, which depends on whether the investor has experienced consumption gains or losses in the past. If the initial consumption exceeds the reference level, increasing the importance of past consumption makes the investor less risk-averse in good times. In this case, a lower reference consumption level reduces the necessity to invest in bonds, as a risk-free asset in good times, investing more of the wealth in stocks is optimal. Also, a smaller reference level is reduced risk-taking incentives in bad times and the optimal portion of wealth invested in stocks. Conversely, if investors have experienced previous losses, increasing the importance of past consumption makes them more risk-averse in good times and more risk-seeking in bad times. Hence, the fraction of wealth invested in stocks decreases in good times and increases in bad times.

Erfani et al. (2018), under the classical utility theory, used a dynamic stochastic general equilibrium model to introduce different policy regimes in which the policymaker, in addition to the common goals of inflation and output stability, also, considers the role of financial stability. The results approved under these conditions, the implementation of monetary policy leads to less volatility in inflation and output.

Bertella et al. (2019) investigated the effect of overconfidence and loss-aversion on stock market price dynamics. Although conventional economics uses homo economicus in asset pricing models and assumes traders' actions are rational, the results have shown the individual behavior of traders and the stock market is not fully understood using traditional economic concepts.

Lejarraga et al. (2019) indicated individuals pay more attention when evaluating losses than evaluating gains. This result is confirmed, even though the majority of participants showed no loss-aversion in their choices.

Scott and Witt (2020) emphasized that the consideration of the effects of behavioral factors such as loss-aversion, reference dependence, and diminishing sensitivity is crucial, particularly when policy implications are considering. Designing policies to influence decisions requires an understanding of how to make decisions. Empirical results appeared that people are more sensitive to the loss than gain when evaluating their options and also, they are risk-seeking when the loss occurs and risk-averse over gain. Also, the loss leads to a greater reduction in value than equivalence to the size of the gain.

Zhao et al. (2020) emphasized that under prospect theory, the phenomenon of loss-aversion proposes that decision-makers give losses higher weights than gains. They indicated that the loss-aversion arises from multiple psychological mechanisms, and the pre-valuation bias is an important determinant of this behavioral tendency. Thus, the results have important implications for how to model behavior under conditions of risk.

Van Bilsen and Laeven (2020) explored the dynamic consumption and portfolio choice under prospect theory. They showed that the optimal consumption is rather insensitive to shocks. In particular, if the individual sufficiently overweights unfavorable events, the model generates an endogenous floor on consumption. In addition, the optimal portfolio profile or the share of wealth invested in the risky stock displays a U-shaped pattern. In this regard, if the individual overweights unfavorable events, the share of assets invested in the risky stock is relatively low. If the individual overweights the probabilities of favorable events, the optimal portfolio profile is substantially larger.

Ebrahimi SarvOlia et al. (2020) investigated the effect of myopia loss-aversion on investment in stocks. They stated that the more the loss-averse investors monitor their performance and evaluate their stock portfolio, the less they invest in stocks when they see losses. Moreover, they emphasized an inverse relationship between the loss-aversion of short-sighted investors and the level of investment, and also, a direct link between the loss aversion of investors who are not myopia and investment in stocks. Additionally, the median loss-aversion coefficient in the stock market of Iran is 2.17.

In general, studies point to the shortcomings of classical theory in describing real-world behavior under uncertainty and emphasize the need of paying attention to psychological considerations to achieve more realistic analyzes. In this regard, the results of the inclusion of behavioral components in the neoclassical utility function were consistent with the basic concepts of the prospect theory, indicating the impact of psychological variables such as loss-aversion and diminishing sensitivity to the changes in stock market price and return dynamics. The findings mainly confirmed the existence of risk-aversion over gains and risk-taking in the face of losses. In general, paying attention to behavioral factors plays a crucial role in decision-making for investors and households under uncertainty. This study attempts to , compare the effectiveness of the monetary policy on macroeconomic dynamics under the utility theory and prospect theory from the perspective of general equilibrium, which little efforts have been made on this issue by the past investigators.

3. Model

In this study, to include loss-aversion in the general equilibrium model, following Santoro et al., 2014; Koszegi and Rabin, 2006 and Yogo, 2008, we use a basic model in which the household utility is a function of consumption and working hours. However, due to the structure of the economy of Iran, some adjustments are made to this basic model. In this regard, instead of interest rates, we used the base money growth rate as a monetary policy tool that necessitates the entry of the demand for real money balances in the general equilibrium model. Hence, we included the real value of money balances besides consumption and working hours in the household utility function. In addition, considering the effect of the investment variable on how households and firms make decisions, this variable is included in the basic model. On the supply side, we assumed the firm uses a partial adjustment approach to determine the optimal price, so only part of the inflation of the previous period is used to adjust the price.

3.1 Households

We present a model in which loss aversion, as a component of the prospect theory, is included in the household utility function. On this matter, household preferences are a function of the real balance of money m_{t+i}, leisure $(1-N_{t+i})$, consumption C_{t+i}, and consumption gains and losses relative to its reference level, X_{t+i}. The household maximizes the expected present discounted value of utility as follow:

$$E_t \sum_{i=0}^{\infty} \beta^i \left[U(C_{t+i}, X_{t+i}) + \frac{1}{(1-b)} m_{t+i}^{1-b} - \chi \frac{N_{t+i}^{1+\gamma}}{1+\gamma} \right] \tag{1}$$

where β is the discount factor, b is the inverse interest elasticity of real money demand, γ is the inverse elasticity of labor supply relative to real wages, and χ stands for a positive and constant parameter. Following

Santoro et al., 2014; Koszegi and Rabin, 2006, and Yogo, 2008, a general class of reference-dependent preferences considered, which defined as follow:

$$U(C,X) = \zeta V(C) + (1-\zeta)G\big(V(C) - V(X)\big) \tag{2}$$

where $\zeta\epsilon[0,1]$. Reference-dependent utility consists of the weighted sum of the two parts, consumption utility, $V(C)$, and gain-loss utility, $G\big(V(C) - V(X)\big)$, (Kahneman and Tversky, 1979). The consumption utility is a neoclassical utility function derived from consumption, C, which is assumed to be continuously differentiable, strictly increasing, and concave for all $C > 0$. The gain-loss represents the utility derived from the deviation of consumption utility, $V(C)$, from its reference level, $V(X)$, where X denotes the reference level of consumption (Santoro et al., 2014: 25). The household derives positive gain-loss utility when C exceeds X and vice versa. For $C \neq X$, marginal utility concerning consumption and its reference level determined respectively as follows:

$$U_C = V'(C)[\zeta + (1-\zeta)G'\big(V(C) - V(X)\big)] > 0 \tag{3}$$

$$U_X = -(1-\zeta)V'(X)\, G'\big(V(C) - V(X)\big) \leq 0 \tag{4}$$

In other words, marginal utility is strictly increasing in consumption and decreasing in the reference level (Yogo, 2008: 132). We assumed the gain-loss utility, $G(Z) = G(V(C) - V(X))$, is strictly increasing and continuous for all Z's, twice differentiable for $Z \neq 0$, and $G(0) = 0$. These two properties indicate monotonicity, i.e., the utility is strictly increasing by the magnitude of gain. Also, $-G(-Z) > G(Z)$ and $G'(-Z) > G'(Z)$, for $Z > 0$. This property includes the concept of loss-aversion, meaning that the impact of a loss is greater than an equal gain by size. Namely, the consumer is more sensitive to deviations from their relative consumption when they are in a bad state than that of a good one (Santoro et al., 2014: 25). Tversky and Kahneman (1992) estimated the value attributed to an average loss is about twice the value attributed to a large gain. The general finding of loss-aversion behavior is that risk-taking to large losses is inconsistent with the traditional assumption of risk-aversion. Also, $G''(Z) \leq 0$ for $Z > 0$ and $G''(Z) \geq 0$ for $Z < 0$. This property refers to diminishing sensitivity, i.e., the marginal effect of the gain or the loss decreases with its magnitude (Santoro et al., 2014: 25). The value function is in the form of S, so it is concave concerning the axis of gains ($Z > 0$) and convex concerning the axis of losses ($Z < 0$) and shows a diminishing sensitivity to changes in both directions. The consequence of diminishing sensitivity makes decision-makers risk-averse to gains (gives relatively fewer value to large gains) and risk-taking to losses (gives relatively fewer value to large losses). To take these properties into account, following Santoro et al., 2014; Köbberling and Wakker, 2005, an exponential gain-loss utility considered as:

$$G(Z) = \begin{cases} \frac{1-exp(-\phi Z)}{\phi} & if\ Z \geq 0 \\ \lambda \frac{\left[exp\left(\frac{\phi}{\lambda} Z\right)-1\right]}{\phi} & if\ Z < 0 \end{cases} \quad ;\ \phi \geq 0, \quad \lambda > 1 \tag{5}$$

where ϕ measures the degree of diminishing sensitivity, and λ indexes the degree of loss-aversion. Also, the function $Z = V\left(C_{i,t}\right) - V(X_{i,t})$ defined logarithmically:

$$Z = log\, C_{i,t} - log\, X_{i,t} \tag{6}$$

Accordingly, in general, two models are considered to specify the form of the household utility function:

$$E_t\ \sum_{i=0}^{\infty} \beta^i \left[\zeta\ logC_{t+i} + (1-\zeta)\left[\frac{1-e^{-\phi z}}{\phi}\right] + \frac{1}{(1-b)} m_{t+i}^{1-b} - \chi \frac{N_{t+i}^{1+\gamma}}{1+\gamma}\right] \qquad z \geq 0 \tag{7}$$

$$E_t\ \sum_{i=0}^{\infty} \beta^i \left[\zeta\ logC_{t+i} + (1-\zeta)\left[\lambda \frac{(e^{(\frac{\phi z}{\lambda})}-1)}{\phi}\right] + \frac{1}{(1-b)} m_{t+i}^{1-b} - \chi \frac{N_{t+i}^{1+\gamma}}{1+\gamma}\right] \qquad z < 0 \tag{8}$$

The maximizing household utility is subject to the following restrictions (in real terms):

$$C_{t+i} + b_{t+i} + m_{t+i} + I_{t+i} = w_{t+i}N_t + R_t^k K_{t+i-1} + (1 + i_{t+i-1})\left(\frac{B_{t+i-1}}{\pi_{t+i}}\right) + \left(\frac{m_{t+i-1}}{\pi_{t+i}}\right) + D_{t+i} \tag{9}$$

$$\mathrm{K_t} = (1-\delta)\mathrm{K_{t-1}} + \mathrm{I_t}\left[1 - \mathrm{s}\left(\frac{\varepsilon_t^{I} \mathrm{I_t}}{\mathrm{I_{t-1}}}\right)\right] \tag{10}$$

where $\mathrm{w_t} = \frac{\mathrm{W_t}}{\mathrm{P_t}}$ is a real wage, $m_t = \frac{M_t}{P_t}$ is the real value of money balances, $b_t = \frac{B_t}{P_t}$ is the real deposits, and $\pi_t = \frac{P_t}{P_{t-1}}$ stands for the gross inflation rate. In addition, I_t is the household's investment, R_t^k is the rate of return on capital, and K_{t-1} is the capital stock in period *t−1*. The right side of Equation (9) represents the household's income sources from the real wage of the labor $w_{t+i}N_t$, the profit from the previous period capital $R_t^k K_{t+i-1}$, the principal and interest of previous period bonds $(1+i_{t+i-1})\left(\frac{B_{t+i-1}}{\pi_{t+i}}\right)$, the previous period real money balances $\left(\frac{m_{t+i-1}}{\pi_{t+i}}\right)$, and the real dividend D_{t+i}. The left side of Equation (9) represents the household's expenditures, namely, real consumption C_{t+i}, real bond b_{t+i}, real money m_{t+i}, and real investment I_{t+i}. In the equation of capital accumulation (10), δ is the rate of capital depreciation, and $s\,(.)$ is a function of the cost of adjusting investment. Following Christiano et al., 2005, we assumed $s(1)=\acute{s}(1)=0$. Kydland and Prescott (1982) argued converting investment into capital is a time-consuming and costly process, and the investment adjustment cost function shows the gap between investment and capital formation. Also, ε_t^I is the investment shock following the first-order autoregressive process, AR(1):

$$\hat{\varepsilon}_t^I=\rho_I\hat{\varepsilon}_{t-1}^I+\epsilon_t^I, \qquad \epsilon_t^I \sim N(0,\sigma_I^2) \tag{11}$$

The household problem is the maximization of utility functions 7 and 8, subject to budget constraints 9 and 10. We assumed λ_t and μ_t are Lagrangian coefficients for the two constraints 9 and 10, respectively. By defining the ratio $q_t=\frac{\mu_t}{\lambda_t}$ as Tobin's Q and solving the above problem, the consumption Euler equations, the labor supply equations, the real money demand equations, the capital pricing dynamics equation, and the investment Euler equation obtained as follows:

$$\beta E_t\left(\frac{(1+i_t)}{\pi_{t+1}}\right)=\frac{\frac{\zeta}{C_t}+\frac{(1-\zeta)}{C_t}\left[e^{-\phi\, ln\left(\frac{C_t}{X_t}\right)}\right]}{\frac{\zeta}{E_t(C_{t+1})}+\frac{(1-\zeta)}{E_t(C_{t+1})}\left[e^{-\phi\, ln\left(\frac{E_t(C_{t+1})}{E_t(X_{t+1})}\right)}\right]} \qquad z\geq 0 \tag{12}$$

$$\beta E_t\left(\frac{(1+i_t)}{\pi_{t+1}}\right)=\frac{\frac{\zeta}{C_t}+\frac{(1-\zeta)}{C_t}\left[e^{\frac{\phi}{\lambda} ln\left(\frac{C_t}{X_t}\right)}\right]}{\frac{\zeta}{E_t(C_{t+1})}+\frac{(1-\zeta)}{E_t(C_{t+1})}\left[e^{\frac{\phi}{\lambda} ln\left(\frac{E_t(C_{t+1})}{E_t(X_{t+1})}\right)}\right]} \qquad z<0 \tag{13}$$

$$w_t=\frac{\chi N_t^\gamma}{\frac{\zeta}{C_t}+\frac{(1-\zeta)}{C_t}\left[e^{-\phi\, ln\left(\frac{C_t}{X_t}\right)}\right]} \qquad z\geq 0 \tag{14}$$

$$w_t=\frac{\chi N_t^\gamma}{\frac{\zeta}{C_t}+\frac{(1-\zeta)}{C_t}\left[e^{\frac{\phi}{\lambda} ln\left(\frac{C_t}{X_t}\right)}\right]} \qquad z<0 \tag{15}$$

$$m_t^{-b} = \frac{i_t}{(1+i_t)}\left[\frac{\zeta}{C_t} + \frac{(1-\zeta)}{C_t}\left[e^{-\phi\, ln\left(\frac{C_t}{X_t}\right)}\right]\right] \qquad z \geq 0 \tag{16}$$

$$m_t^{-b} = \frac{i_t}{(1+i_t)}\left[\frac{\zeta}{C_t} + \frac{(1-\zeta)}{C_t}\left[e^{\frac{\phi}{\lambda}\ln\left(\frac{C_t}{X_t}\right)}\right]\right] \qquad z < 0 \tag{17}$$

$$\frac{E_t(\pi_{t+1})}{(1+i_t)}\left[R_{t+1}^k + (q_{t+1})(1-\delta)\right] = q_t \tag{18}$$

$$1 = q_t - q_t s\left(\frac{\varepsilon_t^I I_t}{I_{t-1}}\right) - q_t I_t \frac{\varepsilon_t^I}{I_{t-1}} \acute{s}\left(\frac{\varepsilon_t^I I_t}{I_{t-1}}\right) + \frac{1}{(1+i_t)} E_t(q_{t+1})(\varepsilon_{t+1}^I)\left(\frac{I_{t+1}}{I_t}\right)^2 \acute{s}\left(\frac{\varepsilon_{t+1}^I I_{t+1}}{I_t}\right) \tag{19}$$

Note that among the first-order conditions of the household, the inclusion of the loss-version component in the household utility function affects the household consumption behavior, the labor supply, and the real money demand, which we will analyze in the results section.

3.2 Firms

3.2.1 Final Goods-producing Firm

The final goods-producing firm purchased $Y_t(j)$ at price $P_t(j)$, to produce the final goods Y_t, using the following production function:

$$Y_t = [\int_0^1 Y_t^{\frac{\theta-1}{\theta}}(j)\, dj]^{\frac{\theta}{\theta-1}} \tag{20}$$

where $Y_t(j)$ is the input of intermediate good j. By maximizing profit, the demand function for intermediate good is determined as follow:

$$Y_t(j) = (\frac{P_t(j)}{P_t})^{-\theta} Y_t \tag{21}$$

where the price elasticity of demand is equal to $\theta > 1$. Equation (21) indicates the demand for intermediate goods is inversely related to its relative price and directly related to total output. By substituting Equation (21) into (20) and simplifying, the price index, P_t, is determined as follow,

$$P_t = [\int_0^1 P_t^{1-\theta}(j) dj]^{\frac{1}{1-\theta}} \tag{22}$$

3.2.2 Intermediate Good Producing Firm

The intermediate good is produced in a monopolistic competition market according to a Cobb-Douglas production function:

$$Y_t(j) = K_{t-1}^{\alpha}(j)\, N_t^{1-\alpha}(j) z_t \tag{23}$$

where $\alpha \in (0,1)$ is the capital share in the production, and z_t is a technology shock that follows an *AR(1)* process:

$$log\, z_t = \rho_z\, log\, z_{t-1} + \epsilon_t^z, \qquad \epsilon_t^z \sim N(0, \sigma_z^2) \tag{24}$$

By minimizing the cost of production to the production function 23, the following first-order conditions obtained:

$$R_t^k = \alpha\, mc_t \frac{Y_t}{K_t} \tag{25}$$

$$w_t = (1-\alpha)\, mc_t \frac{Y_t}{N_t} \tag{26}$$

where R_t^k is the rental rate of capital, w_t is the real wage of labor, and mc_t is the real marginal cost of production. The real marginal cost equation is obtained by rewriting equations 25 and 26 in terms of K_t and N_t, substituting the resulting relations in the production function 23, and after simplifying:

$$mc_t = (\alpha)^{-\alpha}(1-\alpha)^{(\alpha-1)}(R_t^k)^{\alpha}(w_t)^{(1-\alpha)}(z_t) \tag{27}$$

where the real marginal cost is a function of the loss-aversion parameter, so in the case of $V(C_{i,t}) \geq V(X_{i,t})$, it is as follow:

$$mc_t = (\alpha)^{-\alpha}(1-\alpha)^{(\alpha-1)}(R_t^k)^{\alpha}\left(\frac{\chi N_t^{\gamma}}{\frac{\zeta}{C_t}+\frac{(1-\zeta)}{C_t}\left[e^{-\phi\, ln\left(\frac{C_t}{X_t}\right)}\right]}\right)^{(1-\alpha)}(z_t) \tag{28}$$

and in the case of $V(C_{i,t}) < V(X_{i,t})$, the real marginal cost equation is as follow:

$$mc_t = (\alpha)^{-\alpha}(1-\alpha)^{(\alpha-1)}(R_t^k)^{\alpha}\left(\frac{\chi N_t^{\gamma}}{\frac{\zeta}{C_t}+\frac{(1-\zeta)}{C_t}\left[e^{\frac{\phi}{\lambda} ln\left(\frac{C_t}{X_t}\right)}\right]}\right)^{(1-\alpha)}(z_t) \tag{29}$$

We assumed the price stickiness of the firms follows a Calvo form. Each period, a fraction $(1-\omega)$ of the firms can adjust their optimal prices in the price P_t^*, while the remaining cannot, so the profit maximization of firms that have an opportunity to adjust their price is as follow:

$$\max_{P_t(j)} E_t \sum_{s=0}^{\infty} (\omega\beta)^s \Delta_{s,t+s}\left[\frac{P_{t+s}(j)}{P_{t+s}} Y_{t+s}(j) - mc_{t+s}\, Y_{t+s}(j)\right]$$

subject to

$$Y_{t+s}(j) = \left(\frac{P_{t+s}(j)}{P_{t+s}}\right)^{-\theta} Y_{t+s} \tag{30}$$

where $\Delta_{s,t+s} = \frac{\lambda_{t+s}}{\lambda_t}$. For the rest of the firms, we assumed the firm uses a partial adjustment approach to determine the optimal price, so the prices adjusted according to the inflation of the previous periods adjusted by the degree of price indexation ϖ, as shown below:

$$P_t(j) = \pi_{t-1}^{\varpi} P_{t-1}(j) \tag{31}$$

where $\pi_t = \frac{P_t}{P_{t-1}}$ is the gross inflation rate, and $\varpi \in (0,1]$. Accordingly, the general price level in the partial adjustment approach expressed as follow:

$$P_t = [(1-\omega)(P_t^*)^{1-\theta} + \omega(\pi_{t-1}^{\varpi} P_{t-1})^{1-\theta}]^{\frac{1}{(1-\theta)}} \tag{32}$$

Phillips curve in the log-linearized form, under the partial adjustment, can be shown as follow:

$$\hat{\pi}_t = \frac{\varpi}{1+\beta\varpi}\hat{\pi}_{t-1} + \frac{\beta}{1+\beta\varpi}E_t\hat{\pi}_{t+1} + \frac{(1-\omega)(1-\omega\beta)}{\omega(1+\beta\varpi)}\widehat{mc}_t \tag{33}$$

3.3 Equilibrium Characterization

The resource constraint for final goods is as follow:

$$Y_t = C_t + I_t + G_t \tag{34}$$

Since the model excludes the public sector, government expenditure G_t, considered exogenous in the form of an AR(1) process:

$$log\, g_t = \rho_g log\, g_{t-1} + \epsilon_t^g, \qquad \epsilon_t^g \sim N\left(0, \sigma_{\epsilon^g}^2\right) \tag{35}$$

3.4 The Central Bank

To characterize the monetary policy rule, we assume the central bank adjusts the base money growth rate in response to the inflation gap and the output gap, smooths the base money growth rate, and gradually adjusts it to the desired value. Therefore, the policy rule is as follow,

$$\frac{mg_t}{\overline{mg}} = \left(\frac{mg_{t-1}}{\overline{mg}}\right)^{\emptyset_{mg}} \left(\frac{\pi_t}{\bar{\pi}}\right)^{\emptyset_\pi} \left(\frac{Y_t}{\bar{Y}}\right)^{\emptyset_y} e^{\epsilon_t^m} \tag{36}$$

where π_t is inflation and Y_t is output. Also, $\overline{mg}$, $\bar{\pi}$, and $\bar{Y}$ are the steady-state values of the base money growth rate, inflation rate, and output, respectively. Additionally, $\emptyset_{\pi}$, $\emptyset_{Y}$, and $\emptyset_{mg}$ are policy response coefficients chosen by the central bank. Monetary shock, ϵ_t^m follows the AR(1) process:

$$\epsilon_t^m = \rho_{em}\epsilon_{t-1}^m + \sigma_m \tag{37}$$

In addition, the equation of the nominal monetary base growth rate is as follow:

$$mg_t = \left(\frac{m_t}{m_{t-1}}\right)\pi_t \tag{38}$$

In which m_t is the real monetary base.

4. Data, Calibration, and Estimation

4.1 Data

We estimate the model using four quarterly data: GDP without the oil sector, government expenditure, investment, and monetary base growth rate. The sample is over 1990:1 to 2020:3, extracted from the economic time-series database[1] and the economic indicator of the central bank of Iran. All variables are logarithmic and de-trended using the Hodrick-Prescott Filter after seasonal adjustment.

4.2 Calibration and Estimation

Before estimating the equations, we calibrate some of the parameters. For this purpose, the steady-state values of the variables and the steady-state equations of the model[2] are used. Table 1 reports the calibration values:

Table 1. Calibrated Values

Parameter	Description	Values
RK	The steady-state of real interest rates	0.0396
ζ	The weight on the utility function	0.5
b	The inverse of interest elasticity of demand for real money balance	1.1006
$\frac{\bar{Y}}{\bar{K}}$	The steady-state ratio of GDP to the capital stock	0.0593
$\frac{\bar{C}}{\bar{Y}}$	The steady-state ratio of private-sector consumption to GDP	0.545143

1. tsd.cbi.ir
2. Steady-state equations are available upon request.

Parameter	Description	Values
$\frac{\bar{G}}{\bar{Y}}$	The steady-state ratio of public sector expenditures to GDP	0.130733
$\frac{\bar{I}}{\bar{Y}}$	The steady-state ratio of investment to GDP	0.324123

Source: Research finding.

In the following, we estimate the model once without the loss-aversion parameter (Equation 7) and again with it (Equation 8), using the Bayesian method[1]. Also, for log-linearizing of the first-order conditions, the Uhlig log-linear method is used. Appendix (A) presents the logarithm-linear equations. Also, the results of the Identification test of Iskrev 2010 in both models show all parameters identifiable. These results are presented in Appendix (B).

Table 2 presents the prior distributions and means of the parameters, the posterior means, and the 5 and 95 percentiles probability intervals for the estimated parameters.

Table 2. The Estimation Results

	Coef.	Description	Prior			Posterior		
			Density	Mean	Std.	Mean	[5%]	[95%]
No Loss-aversion	ϕ	Declining sensitivity	Gamma	0.853	0.05	0.8219	0.7423	0.8988
Loss-aversion[2]						-	-	-
No Loss-aversion	λ	Loss-aversion Parameter	-	-	-	-	-	-
Loss-aversion			Gamma	2.25	0.5	2.0781	1.3451	2.8368
No Loss-aversion	γ	The inverse of elasticity of labor supply	Gamma	2.21	0.01	2.2103	2.1936	2.2264
Loss-aversion						2.2103	2.1937	2.2270
No Loss-aversion	δ	Depreciation rate	Beta	0.028	0.01	0.043	0.0224	0.0614
Loss-aversion						0.0439	0.0242	0.0631
No Loss-aversion	α	Capital share in production	Beta	0.83	0.01	0.8353	0.8194	0.8514
Loss-aversion						0.8394	0.8229	0.8551
No Loss-aversion	β	Discount factor	Beta	0.962	0.01	0.962	0.9461	0.9779
Loss-aversion						0.9597	0.9428	0.9764
No Loss-aversion	ω	Percentage of firms that are unable to adjust their prices	Beta	0.78	0.01	0.7720	0.7553	0.7879
Loss-aversion						0.7642	0.7475	0.7807
No Loss-aversion	ω	Percentage of firms that are unable to adjust their prices	Beta	0.78	0.01	0.7720	0.7553	0.7879
Loss-aversion						0.7642	0.7475	0.7807
No Loss-aversion	ω	Percentage of firms that are unable to adjust their prices	Beta	0.78	0.01	0.7720	0.7553	0.7879
Loss-aversion						0.7642	0.7475	0.7807

1. For this purpose, we have used version 4.7 of Dynare software.
2. The results of the test of identifying the parameters showed *collinearity* between parameters of declining sensitivity and loss-aversion. Therefore, in estimating the model with the loss aversion, we used the posterior value obtained from the model without loss-aversion as the initial value.

	Coef.	Description	Prior			Posterior		
			Density	Mean	Std.	Mean	[5%]	[95%]
No Loss-aversion	ω	Percentage of firms that are unable to adjust their prices	Beta	0.78	0.01	0.7720	0.7553	0.7879
Loss-aversion						0.7642	0.7475	0.7807
No Loss-aversion	$\emptyset_{mg}$	The policy coefficient of the monetary base growth rate in the monetary policy rule	Norm	0.38	0.05	0.3346	0.2529	0.4149
Loss-aversion						0.3092	0.2289	0.3892
No Loss-aversion	$\emptyset_{\pi}$	The importance of inflation in the monetary policy rule	Norm	-2.9	0.06	-2.8829	-2.9831	-2.7839
Loss-aversion						-2.8818	-2.9779	-2.7812
No Loss-aversion	$\emptyset_{y}$	The importance of the output gap in the monetary policy rule	Norm	-0.85	0.06	-0.8227	-0.9201	-0.7274
Loss-aversion						-0.8457	-0.9430	-0.7533
No Loss-aversion	ρ_m	AR(1) coefficient of a monetary shock	Beta	0.3	0.04	0.1679	0.1296	0.2064
Loss-aversion						0.1654	0.1291	0.2041
No Loss-aversion	ρ_I	AR(1) coefficient of investment shock	Beta	0.4	0.04	0.2867	0.2338	0.3377
Loss-aversion				0.5		0.3651	0.3109	0.4225
No Loss-aversion	ρ_z	AR(1) coefficient of the technology shock	Beta	0.6	0.04	0.6197	0.5604	0.6803
Loss-aversion				0.5		0.5083	0.4441	0.5693
No Loss-aversion	ρ_g	AR(1) coefficient of government expenditure shock	Beta	0.5	0.04	0.4310	0.3692	0.4925
Loss-aversion						0.4281	0.3661	0.4870
No Loss-aversion	ϱ	The inverse of elasticity of the cost of capital adjustment	Gamma	0.254	0.04	0.2935	0.2233	0.3659
Loss-aversion						0.3090	0.2345	0.3836
No Loss-aversion	ϖ	the degree of price indexation	Beta	0.68	0.04	0.6801	0.6143	0.7451
Loss-aversion						0.6670	0.6002	0.7363
No Loss-aversion	ϵ_m	The standard deviation of a monetary shock	Inverted Gamma	0.03	inf	0.1838	0.1608	0.2071
Loss-aversion				0.042		0.1826	0.1603	0.2058
No Loss-aversion	ϵ_g	The standard deviation of government expenditure shock	Inverted Gamma	0.078	inf	0.0954	0.085	0.1057
Loss-aversion				0.07		0.095	0.0843	0.1052
No Loss-aversion	ϵ_z	The standard deviation of the technology shock	Inverted Gamma	0.04	inf	0.0915	0.0783	0.1050
Loss-aversion				0.049		0.0799	0.0677	0.0911
No Loss-aversion	ϵ_I	The standard deviation of investment-specific shock	Inverted Gamma	0.07	inf	0.1361	0.1190	0.1536
Loss-aversion				0.064		0.1459	0.1264	0.1659

Source: Research finding.

The estimation results showed under the presence and absence of loss-aversion parameter, the technology shock has the most durability, and the monetary shock has the least in the Iranian economy. Also, the estimated value of the loss-aversion parameter is 2,078, which is very close to the findings of Ebrahimi Sarv Olia et al., 2020; Tversky and Kahneman, 1992. Figures 1 and 2 show the prior and posterior densities of the parameters in the absence of the loss-aversion parameter and the presence of that, respectively.

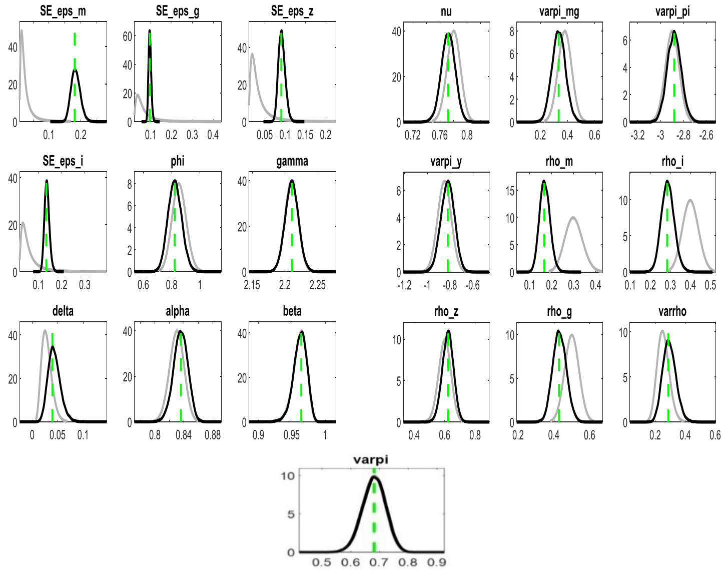

Figure 1. Prior and Posterior Estimate of Parameters in the Absence of the Loss-Aversion
Source: Research finding.

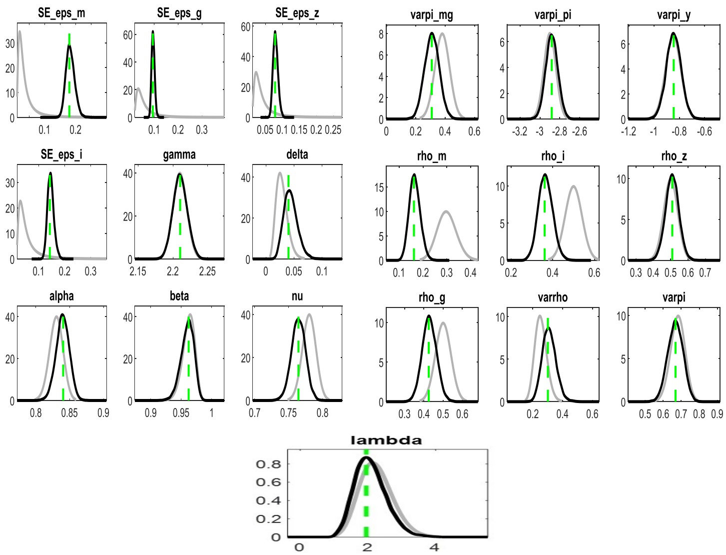

Figure 2. Prior and Posterior Estimate of Parameters in the Presence of the Loss-Aversion
Source: Research finding.

Bayesian estimation results for both models showed the acceptance rate for all three chains used range from 0.25 to 0.4 and was approximately 30%. Also, Brooks and Gelman's 1980 diagnostic test used to check the accuracy of the estimates. The examination of the three indicators, namely, interval, m2, and m3, representing the 80% confidence interval around the mean, variances, and the third moments of the parameters, respectively, indicates convergence and relative stability in all moments. Appendix C presents these results.

In the following, to investigate the effect of prospect theory on the basic model, we used the posterior means of the parameters estimated in Table 2. The results of replacing the estimated parameters in the Log-linearized Form of the consumption Euler equation under the conventional utility (A.1) and prospect theory (A.4) are in the form of equations (39) and (40), respectively.

$$\hat{c}_t = 0.7744\, E_t(\hat{c}_{t+1}) + 0.2255\, \hat{c}_{t-1} - 0.5488\left(\hat{\imath}_t - E_t(\hat{\pi}_{t+1})\right) \tag{39}$$

$$\hat{c}_t = 1.327\, E_t(\hat{c}_{t+1}) - 0.3271\, \hat{c}_{t-1} - 1.654\left(\hat{\imath}_t - E_t(\hat{\pi}_{t+1})\right) \tag{40}$$

According to the conventional utility function (39), there is a direct relationship between the current period consumption with the expected consumption and the previous period consumption. In addition, consumption is a forward-looking variable so that in determining the current period consumption, people allocate more weight to the future period consumption. Under both conventional utility function and prospect theory, there is an inverse relationship between real interest rates and current period consumption. Nevertheless, under the prospect theory, loss-aversion and the fear of losses due to rising inflation leads to an overestimation of people's inflation expectations, which in turn reduces the real interest rate. The substitution effect of a lower interest rate is that current consumption is now less expensive (because less saving will lead to even less consumption in the future), so consumers will tend to increase their consumption today to a greater extent. Also, increasing consumption and reducing savings in the previous period will reduce the wealth of consumers in the current period, which will cause consumers to consume less in the current period.

The results of estimating the Log-linearized Form of the labor supply equation under the conventional utility (A.2) and prospect theory (A.5) are in the form of equations (41) and (42), respectively.

$$\hat{w}_t = 2.2103\ \hat{N}_t + 1.411\ \hat{c}_t - 0.411\ \hat{c}_{t-1} \tag{41}$$

$$\hat{w}_t = 2.2103\ \hat{N}_t + 0.8022\ \hat{c}_t + 0.1977\ \hat{c}_{t-1} \tag{42}$$

Under prospect theory (42), there is a direct relationship between the past period's consumption and the current period's real wages. An increase in past consumption leads to an increase in the aggregate demand and hence inflation. Under these circumstances, the fear of losses due to rising inflation causes people to demand higher nominal wages to maintain their purchasing power, and therefore in the current period, real wages rise**.** In contrast, in the conventional utility function (41), there is an inverse relationship between the past period's consumption and the current period's real wages because people are not sensitive to rising inflation and therefore do not ask for higher nominal wages. This will lead to a decrease in the current period's real wages. In addition, under both theories, there is a direct relationship between labor supply and real wages.

The results of estimating the Log-linearized Form of the real money demand equation under the conventional utility (A.3) and prospect theory (A.6) are in the form of equations (43) and (44), respectively.

$$\hat{m}_t = -0.8353\ \hat{\imath}_t + 1.281\ \hat{c}_t - 0.3733\ \hat{c}_{t-1} \tag{43}$$

$$\hat{m}_t = -0.8353\ \hat{\imath}_t + 0.7289\ \hat{c}_t + 0.1796\ \hat{c}_{t-1} \tag{44}$$

Under the conventional utility function (43), with increasing consumption and decreasing savings in the past period, the level of wealth and income of individuals in the future decreases, reducing transactions demand for money in the current period. However, under prospect theory (44), the loss-aversion's agents are more sensitive to reduced income and therefore reduce the current period consumption and keep more cash.

4.3 Impulse-Response Analysis and Comparison under the Presence and Absence of the Loss-aversion

We simulated two models, with and without the loss-aversion parameter. For this purpose, we used the posterior means in Table 1 as the initial values for the simulation of parameters.

Figure 3 depicts the response of key variables in the model, following an expansionary monetary shock. As shown, the nominal interest rate declines, which encourages investment demand. The higher demand for goods leads to a rise in output and inflation. However, the results showed under the loss-aversion parameter, interest rates decrease with less intensity, and inflation and output increase in the short run, although negligible. The intuition is as follows: under the loss-aversion, the fear of losses due to rising inflation leads to an overestimation of people's inflation expectations, and therefore, inflation increases more in the short run. The higher inflation reduces the purchasing power of money and the expected return on bonds and money relative to real assets, which, in turn, increases the preference of people to maintain real assets instead of money and bonds. Moreover, by higher expected inflation, the cost of borrowing decreases, and the supply of bonds increases. Overall, both results showed that interest rate increases as expected inflation increases. Therefore, inflation expectations cause the initial reduction of interest rates due to increased money supply (liquidity effect) somewhat offset. Hence, under loss-aversion, the interest rate decreases with less intensity.

After about two periods, interest rates begin to rise, and output and inflation decrease, so the variables return to their steady-state.

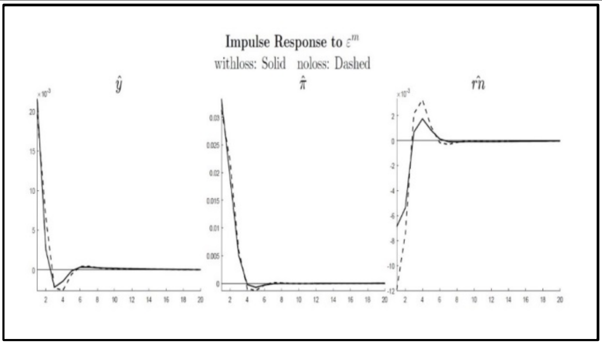

Figure 3. Comparison of the Response of Variables to the Monetary Shock under the Presence and Absence of Loss-Aversion
Source: Research finding.

Also, Figure 4 depicts the response of the key variables in the model following the government expenditure shock. The results indicated expansionary financial shock leads to an increase in the interest rate. Overall, this shock increases inflation and output. However, under the prospect theory, people expect the government to sell bonds to the public to cover its expenditure. Therefore, they expect that inflation will decrease in the future and hence will have more demand for bonds, which will lead to lower interest rates. Thus, comparing the results of these two models showed that under the loss-aversion, the implementation of fiscal policy leads to less volatility in macroeconomic variables such as inflation and output. Therefore, the financial policymaker's attention to the loss-aversion behavior of economic agents in implementing policies would improve welfare outcomes in the economy.

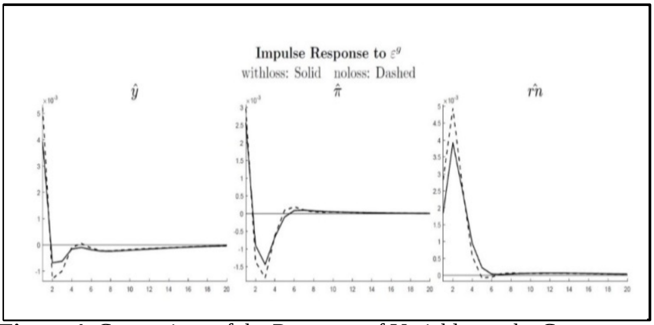

Figure 4. Comparison of the Response of Variables to the Government Expenditure Shock under the Presence and Absence of the Loss-Aversion
Source: Research finding.

5. Conclusion

After studying numerous articles regarding behavioral economics, the question arises as to Kahneman and Tversky's prospect theory influences the effectiveness of the monetary policy. To address this issue, we introduced loss-aversion as an essential component of the prospect theory in the household utility function and implemented the general equilibrium model once with this feature in the utility function and once without it.

The results of Bayesian estimation for the period 1990:1 to 2020:3 in the Iranian economy showed that under prospect theory, the inclusion of the loss-aversion component affects the household consumption behavior, the labor supply, and the real money demand. In addition, following an expansionary monetary shock, the interest rate decreases with less intensity, under the prospect theory. Also, inflation and output increase in the short run, although negligible. The intuition is as follows: under the loss-aversion, the fear of losses due to rising inflation leads to an overestimation of people's inflation expectations, and therefore, inflation increases more in the short run. The higher inflation reduces the purchasing power of money and the expected return on bonds and money relative to real assets, which, in turn, increases the preference of people to maintain real assets instead of money and bonds. Also, by higher expected inflation, the cost of borrowing decreases, and the supply of bonds increases. Overall, both results illustrated that the interest rate increases as expected inflation increases. Consequently, inflation expectations cause the initial reduction of interest rates due to the liquidity effect somewhat offset. Hence, under loss-aversion, the interest rate decreases with less intensity.

In addition, the results showed that expansionary financial shock leads to an increase in the interest rate. Altogether, this shock increases inflation and output. However, under the prospect theory, people expect the government to sell bonds to the public to cover its expenditure. Therefore, they expect that inflation will decrease and hence will have more demand for bonds, which will lead to lower interest rates. Thus, comparing these two models under the loss-aversion, the implementation of fiscal policy leads to less volatility in macroeconomic variables such as inflation and output. Therefore, the financial policymaker's attention to the loss-aversion behavior of economic agents in implementing policies would improve welfare outcomes in the economy.

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Appendix 1. The Log-linearized Form of Equations

$$\hat{c}_t = \frac{\phi(1-\zeta)}{1+2\phi(1-\zeta)}\hat{c}_{t-1} + \left[\frac{1+\phi(1-\zeta)}{1+2\phi(1-\zeta)}\right]E_t(\hat{c}_{t+1}) - \left[\frac{1}{1+2\phi(1-\zeta)}\right]\left(\hat{\imath}_t - E_t(\hat{\pi}_{t+1})\right), \quad z \geq 0 \tag{A1}$$

$$\widehat{w}_t = \gamma\widehat{N}_t + [1+\phi(1-\zeta)]\hat{c}_t - \phi(1-\zeta)\hat{c}_{t-1}, \qquad z \geq 0 \tag{A2}$$

$$\widehat{m}_t = -\left[\frac{1}{b(1+i)}\right]\hat{\imath}_t + \left[\frac{1+\phi(1-\zeta)}{b}\right]\hat{c}_t - \left[\frac{\phi(1-\zeta)}{b}\right]\hat{c}_{t-1}, \qquad z \geq 0 \tag{A3}$$

$$\hat{c}_t = \left[\frac{1-(1-\zeta)\left(\frac{\phi}{\lambda}\right)}{1-2\left(\frac{\phi}{\lambda}\right)(1-\zeta)}\right]E_t(\hat{c}_{t+1}) - \left[\frac{(1-\zeta)\left(\frac{\phi}{\lambda}\right)}{1-2\left(\frac{\phi}{\lambda}\right)(1-\zeta)}\right]\hat{c}_{t-1} - \left[\frac{1}{1-2\left(\frac{\phi}{\lambda}\right)(1-\zeta)}\right]\left(\hat{\imath}_t - E_t(\hat{\pi}_{t+1})\right), Z < 0 \tag{A4}$$

$$\widehat{w}_t = \gamma \widehat{N}_t - \left[-1 + (1-\zeta)\left(\frac{\phi}{\lambda}\right)\right]\hat{c}_t + \left[(1-\zeta)\left(\frac{\phi}{\lambda}\right)\right]\hat{c}_{t-1}, \quad Z < 0 \tag{A5}$$

$$\widehat{m}_t = -\left[\frac{1}{b(1+i)}\right]\hat{\imath}_t - \left[\frac{-1+(1-\zeta)\left(\frac{\phi}{\lambda}\right)}{b}\right]\hat{c}_t + \left[\frac{(1-\zeta)}{b}\left(\frac{\phi}{\lambda}\right)\right]\hat{c}_{t-1}, \quad Z < 0 \tag{A6}$$

$$E_t(\hat{\pi}_{t+1}) - \frac{i}{1+i}\hat{\imath}_t + \frac{R^K}{R^K+q(1-\delta)}E_t\left(\widehat{R}^K_{t+1}\right) + \frac{q(1-\delta)}{R^K+q(1-\delta)}E_t(\hat{q}_{t+1}) = \hat{q}_t \tag{A7}$$

$$\hat{I}_t = \frac{\varrho}{(1+\beta)}\hat{q}_t + \frac{1}{(1+\beta)}\hat{I}_{t-1} + \frac{\beta}{(1+\beta)}E_t\left(\hat{I}_{t+1}\right) - \frac{1}{(1+\beta)}\hat{\varepsilon}^I_t + \frac{\beta}{(1+\beta)}E_t(\hat{\varepsilon}^I_{t+1}),\ \varrho = \frac{1}{s''(1)} \tag{A8}$$

$$\hat{Y}_t = \alpha \widehat{K}_{t-1} + (1-\alpha)\widehat{N}_t + \hat{z}_t \tag{A9}$$

$$\widehat{w}_t - \widehat{R}^k_t = \widehat{K}_{t-1} - \widehat{N}_t \tag{A10}$$

$$\widehat{mc}_t = \alpha \widehat{R}^k_t + (1-\alpha)\widehat{w}_t + \hat{z}_t \tag{A11}$$

$$\hat{\pi}_t = \frac{\varpi}{1+\beta\varpi}\hat{\pi}_{t-1} + \frac{\beta}{1+\beta\varpi}E_t\hat{\pi}_{t+1} + \frac{(1-\omega)(1-\omega\beta)}{\omega(1+\beta\varpi)}\widehat{mc}_t \tag{A12}$$

$$\hat{Y}_t = \left(\frac{\bar{C}}{\bar{Y}}\right)\left(\hat{C}_t\right) + \left(\frac{\bar{I}}{\bar{Y}}\right)\left(\hat{I}_t\right) + \left(\frac{\bar{G}}{\bar{Y}}\right)\left(\hat{G}_t\right) \tag{A13}$$

$$\widehat{mg}_t = \left(\emptyset_{mg}\right)(\widehat{mg}_{t-1}) + (\emptyset_\pi)\hat{\pi}_t + \left(\emptyset_y\right)\hat{Y}_t + \epsilon^m_t \tag{A14}$$

$$\widehat{mg}_t = \widehat{m}_t - \widehat{m}_{t-1} + \hat{\pi}_t \tag{A15}$$

$$\hat{z}_t = \rho_z\, \hat{z}_{t-1} + \epsilon_z \tag{A16}$$

$$\hat{\varepsilon}^I_t = \rho_I \hat{\varepsilon}^I_{t-1} + \epsilon_I \tag{A17}$$

$$\hat{\epsilon}_t = \rho_m\, \hat{\epsilon}_{t-1} + \epsilon_m \tag{A18}$$

$$\hat{g}_t = \rho_g\, \hat{g}_{t-1} + \epsilon_g \tag{A19}$$

Appendix 2. Parameter Identification Test Results

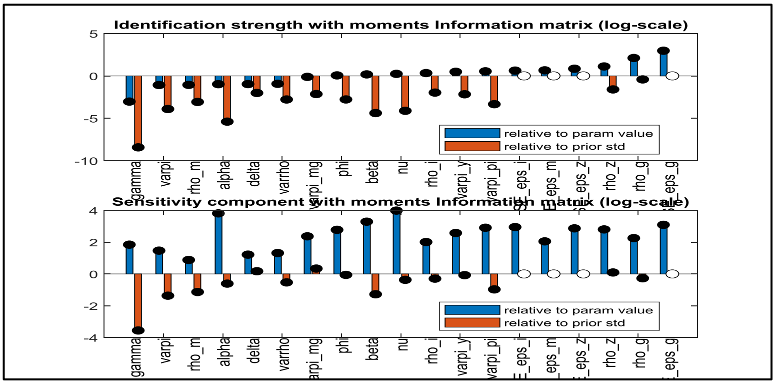

Figure A1. Parameter Identification Test in the Absence of the Loss-Aversion
Source: Research finding.

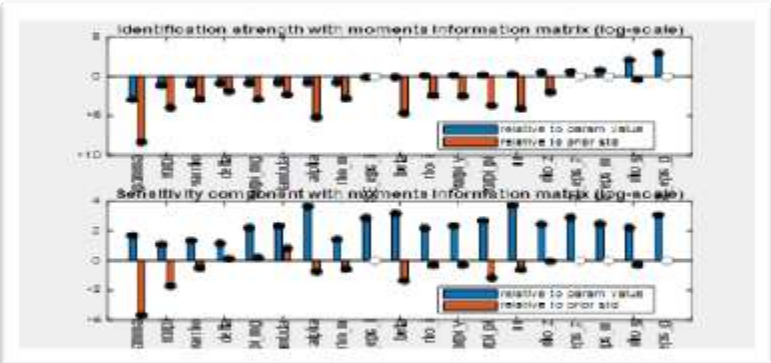

Figure A2. Parameter Identification Test in the Presence of the Loss-Aversion
Source: Research finding.

Appendix 3. Diagnostic Test Results of Bayesian Estimation Accuracy

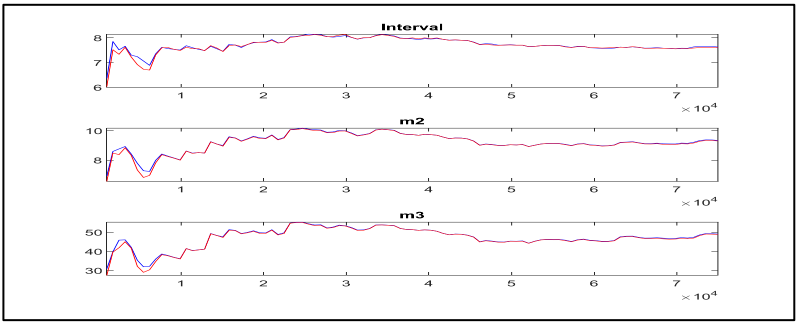

Figure A3. Diagnostic Test in the Absence of the Loss-Aversion
Source: Research finding.

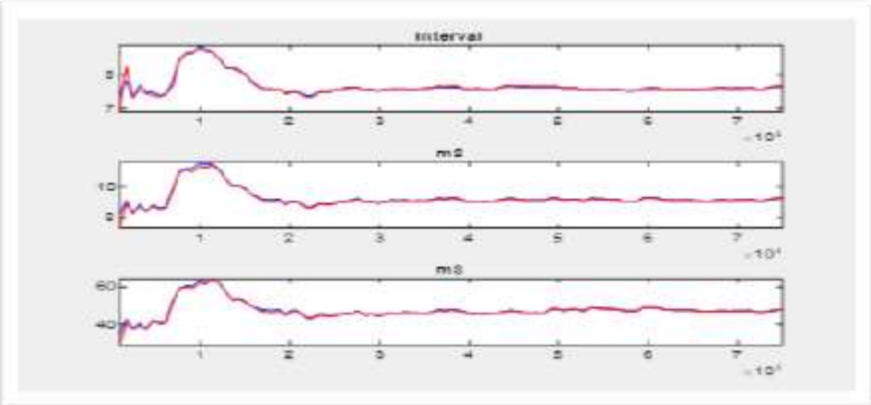

Figure A4. Diagnostic Test in the Presence of the Loss-Aversion
Source: Research finding.