Advances in Mathematical Finance & Applications
www.amfa.iau-arak.ac.ir
Print ISSN: 2538-5569
Online ISSN: 2645-4610

Original Research

Optimal Inflation Rate Measurement for Minimizing Economic Inequality: The Dynamic Stochastic General Equilibrium Approach

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ARTICLE INFO
Article history:
Received 2022-08-31
Accepted 2023-02-23

Keywords:
Optimal Inflation Rate
Distribution of Income
Dynamic Stochastic General Equilibrium(DSGE)

ABSTRACT
The equitable distribution of income is considered as a development indicator in countries. Thus it is required to identify factors impacting the equitable distribution of income to make suitable policies to improve it. The present study aims to determine the optimal inflation rate in order to minimize income inequality by using the dynamic stochastic general equilibrium (DSGE) method in Iran during 1997-2017. The results revealed the optimal inflation rate to be 3.74%. An increase or reduction in the optimal inflation rate of 3.74% enhances income inequality. Thus, the government should target the inflation rate in its policies to achieve minimum inequality. Hence, inequality fluctuations (rises and declines) will be probable.

1 Introduction

Inflation is among the most important factors impacting the inequitable distribution of income in the economic literature. It is an essential problem in economics and imposes numerous negative impacts, including non-optimal resource allocation, income inequality, slow economic growth, and future uncertainty. These problems are so important that almost no economic study can ignore inflation (Many researchers in the literature attempted to find solutions to reduce inflation. Some researchers claimed inflation to result from the major deficiencies of capitalism) [15]. Given the inverse relationship between the inflation rate and the unemployment rate and its impact on the improvement of production and employment, inflation is inevitable in incomplete employment status. However, the main problem is that what the optimal policy-induced inflation rate should be to not only avoid rising income inequality (Distribution of income is a well-known context in the economic literature of Iran; however, despite its considerable extensiveness, it has not enjoyed the required deepness. Michael Todaro proposed a short and valid definition for national income distribution as “Who earns how much of what” [3].) while producing the maximum effectiveness but also improve it.

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Economic changes in countries in recent years, particularly in developing countries that experienced a larger income gap among different classes of their societies in spite of their relative economic growth have made economists and policy-makers pay more attention to the distribution of income and reduce income differences and consequent social tensions by making optimal economic policies (The concept of income inequality has been the subject of many philosophers, statistical researchers, political theorists, sociologists, and economists. The complication of measuring this concept begins from the fact that "income inequality" creates different concepts in the minds of different individuals, depending on their prejudice and knowledge) [32]. since inflation reduces purchasing power and harms those that have fixed income and those that cannot increase their income as inflation rises [12]. At the same time, inflation decreases the values of government transfer payments, such as cash subsidies and employment insurance payments. Thus, as transfer payment receivers typically come from the most impoverished class of society, inflation will enhance inequality if such payments are not adjusted based on inflation. Inflation also decreases inequality by reducing the real values of monetary assets since the poor have a larger portion of their monetary assets in the form of cash than the rich and thus, they are more exposed to the inflation-reduced purchasing power [12]. The difference in the power of different classes to hedge inflation effects is the most important impact of inflation on inequality. Richer classes are typically abler to protect themselves against inflation-caused shocks. They can invest in a group of assets whose returns either have a weak correlation with inflation or can grow at a higher rate than the inflation rate on average, hedge the effect of inflation. This is not easy for low-income classes since such activities require a minimum level of assets due to the incompleteness of investment and financial markets, and such classes cannot provide it.

Hence, the inflation tax asymmetry resulting from the unequal distribution of wealth is a major reason in support of price stability since monetary assets account for a large portion of the portfolios of low-income households. Thus, the inflation tax burden is inappropriately imposed on the poor. In other words, this is a key justification for confirming price stability as a contribution to the reduction of inequality and poverty. Moligan and Salay-Martin indicated that the chance of enjoying inflation-protecting financial technologies is directly related to the income level [30]. This effect can be clearly observed in Iran. Moreover, the portion of income saved in the form of cash assets to be used in unpredicted emergency situations varies, depending on the income level; individuals with higher income have to keep a larger portion of their income, which makes them more vulnerable to inflation corrosion. The increased inflation also enhances inequality by slowing down economic growth since fluctuations and uncertainty rise as inflation rises, and this reduces investment and consequently, economic growth. On the other hand, Romer [31] demonstrated that the poor were typically debtors and since the real values of nominal debts reduce as inflation increases, income was redistributed from creditors to debtors. However, as such debts are not very large (at least on average), the economic importance of this variation is slight. Empirical studies conducted in Iran suggest that inflation has worsened the distribution of income [2].

Considering the adverse impacts of income inequality on the economy of countries and the inflation of Iran, it is particularly important to investigate the impact of inflation on income inequality. To cope with inequitable distribution of income, it is required to identify factors influencing the inequitable distribution of income and make policies to improve the inequality at different levels and deciles of society based on their effects on the distribution of income [21]. Although the problem is important, and theoretical studies have been conducted on the relationship between inflation and income inequality, a small number of studies focused on the relationship between the two variables [16]. However,

despite their considerable revenues, income inequalities in developing countries have led policy-makers and statesmen to employ appropriate economic policies in order to reduce income gaps and consequent social tensions [3]. Given the importance of income distribution and the considerable relationship between the optimal inflation rate and income inequality, by adopting the dynamic stochastic general equilibrium (DSGE) approach, the present study determines the optimal inflation rate to minimize income inequality among households that distinctly keep their assets in the form of profitable assets and households that mainly keep cash [33].

The remainder of the study is organized as follows: Section 2 provides the theoretical foundations; Section 3 reviews the literature; Section 4 proposes hypotheses; Section 5 describes the proposed model; Section 6 provides the results; Section 7 concludes the work; and, Section 8 makes suggestions for future works.

2 Theoretical Foundations

Financial development improves economic growth. A number of empirical studies, such as Degrigorior and Gidoni indicated that financial development considerably reduced economic growth in the Latin American countries in the 1970s and 1980s. It should be noted that these countries had relatively large inflation rates in the two decades. This led the World Bank to issue a financial circular that recommended developing countries not to pursue financial reform unless their inflation rates had reduced sufficiently. Apparently, a large inflation rate was assumed to negatively impact the performance of financial markets and change the relationship between financial development and economic growth. In their empirical study, Boyd et al. [34] proved the inflation rate to be negatively related to the performance of financial markets. This probability was overlooked in many studies in theoretical literature.

The theoretical literature has described mechanisms in which even the predictable rise of inflation is inconsistent with the ability of the financial sector to efficiently allocate resources. Particularly, recent theories emphasized on the asymmetry of information in credit markets and indicated how an increased inflation rate positively influenced credit market friction and negatively impacted the performance of the financial sector and consequently, the long-term activities of the real part of the economy [35] .

A shared feature of these theories is that they consider a very endogenous type of information friction. Given this feature, a rise in the inflation rate of the real return rate generally diminishes not only money but also the entire assets. An implicit decline in the real return intensifies the friction of the credit market. Since such friction leads to credit rationing, credit rationing is intensified as much as inflation. As a result, the financial sector provides lower loans, resource allocation becomes less efficient, and the activities of financial intermediaries in investment reduce due to the negative consequents. A decline in the formation of capital negatively impacts long-term economic performance and activity of the stock market [35, 36].

Moore, Choi et al., and Azariadis and Smith emphasized that when inflation is high enough, since the returns of deposits reduce, it leads to the reduced deposits and reduced number of depositors, intensified information friction, and consequently, scarce financial credits. Moreover, Schreft and Huybens and Smith [36], and Huybens and Smith [35] proposed the idea that economies with high inflation rates will not reach or even become close to a stable condition in which their capital reserves are high. In addition, due to higher rates resulting from high inflation rates, such economies clearly offer less efficient financial markets. In the inflation situation, financial intermediation has become more difficult since the information flows of the real investment returns have become less certain and less available. This will lead to loaners mostly focusing on short-term objectives in their asset portfolios and limit their long-term loans. Eventually, a major portion of loans is directed toward loans that are most likely to be used

to respond to operation costs. Inflation can also suppress financial intermediation by eroding the usefulness of monetary assets and impacting policy decisions that distort the financial structure [37]. According to Friedman's Optimum Monetary Quantity Rule, resource allocation is performed completely and optimally in a monetary economy that is in a complete competition when the nominal productivity rate is zero. In this case, inflation-caused disturbance is minimized. Thus, the optimal inflation rate is the one at which the nominal productivity is zero. When the inflation rate exceeds the optimal level in an economy, the nominal interest rate exceeds zero. In this case, Pareto optimum allocation does not occur. As a result, the social welfare reduces, creating welfare costs. According to Friedman, the optimal social point is the one at which the final social benefit of maintaining the last currency is equal to the final cost of money from the social view. Since the cost of producing the last currency is zero for the community, the final social benefit of maintaining money, or the nominal interest rate, should be zero. Thus, in such a political system, the inflation rate will be equal to the negative quantity of the real interest rate. In fact, the optimal inflation rate is negative in Freidman's rule (Sidrauski's pattern is a suitable framework to calculate the optimal inflation rate in a steady state since when money is directly incorporated in the utility function, the lower maintenance level of money balances influences the welfare level as a result of the higher inflation rate. The optimal inflation is obtained when the minimum loss has been imposed on the social welfare function [6]). [38]

2.1 Distribution of Income

Sahot [49] divided income distribution theories into the ability theory, stochastic theory, individual choice theory, human capital theory, theories of educational inequalities, inheritance theory, lifecycle theory, public income redistribution theories, more complete theories, and theories of distributive justice. Kaasa suggested that these factors can be divided into five groups, including economic growth and development, demographic factors, political factors, historical, cultural, and natural factors, and macroeconomic factors. According to the literature, inflation is a factor affecting inflation income inequality. However, the effect of inflation on income inequality is not theoretically known.

2.2 Impact of Inflation on Income Inequality

The real values of nominal debts decline as the inflation rate rises. Thus, income is redistributed from creditors to debtors. In other words, debtors benefit from inflation since they pay debts whose purchasing power has declined. Since the poor are usually debtors on average, the rise of inflation through this channel benefits them on average and reduces inequality. However, Romer and Romer [31] emphasized that although the poor are debtors, this effect's economic significance may be slight since such debts are not significant [41].

Additionally, the Philips curve assumes an inverse relationship between unemployment and inflation, i.e., a high inflation level reduces unemployment. Given that unemployment is one of the most important factors influencing the level of poverty in society. A rise in inflation can contribute to improving income distribution and reducing poverty by decreasing unemployment [26].

If nominal wages remain unchanged, the real income declines as inflation rises, and those with fixed income, who cannot change their income in proportion to price rises (e.g., governmental employees, workers, whose wages are not based on inflation) undergo losses, with reduced purchasing power. This effect is not the same for everyone since some individuals, particularly those with high income, may receive no fixed income, with their nominal income rising as inflation rises, while the nominal income of the low-income class remains unchanged. Therefore, income inequality rises through this channel as

inflation rises. Reviewing the results of Shiller and Easterly and Fisher indicates the importance of this effect in practice [41].

The abilities of different classes for compensating for the inflation-reduced purchasing power are different. Typically, wealthy classes are abler to protect themselves from inflation-induced shocks. Such individuals typically invest in a portfolio of different assets, covering the effects of inflation. This, however, is not easy for low-income classes since they require a minimum level of assets to engage in such activities, but they cannot provide it. Thus, the poor keep a larger portion of their assets in cash than the rich, which exposes them to inflation-reduced purchasing power more than the rich. Therefore, an increase in inflation increases inequality by decreasing the real values of monetary assets [16]. Inflation reduces the real values of governmental transfer payments, such as cash subsidies and unemployment insurance payments. Since transfer payment receivers are typically among the poorest classes of the population, inflation reduces inequality if such payments are not adjusted by inflation [48]. A decline in inflation can improve long-term growth by bringing stability in macroeconomics and motivating investment. Although the relationship between income and growth is not known empirically and theoretically, stable long-term growth is expected to reduce income inequality. Thus, inequality is predicted to rise due to reduced long-term growth as inflation rises; however, the positive effect of reduced inflation is the case only in countries with high initial inflation (typically hyperinflation). In economies with medium or low inflation, inflation is less likely to create a degree of macroeconomic instability to reduce investment and thus, long-term growth. Fig. 1 demonstrates a summary of the channels and negative and positive (dual) effects of (predicted) long-term inflation in income inequality.

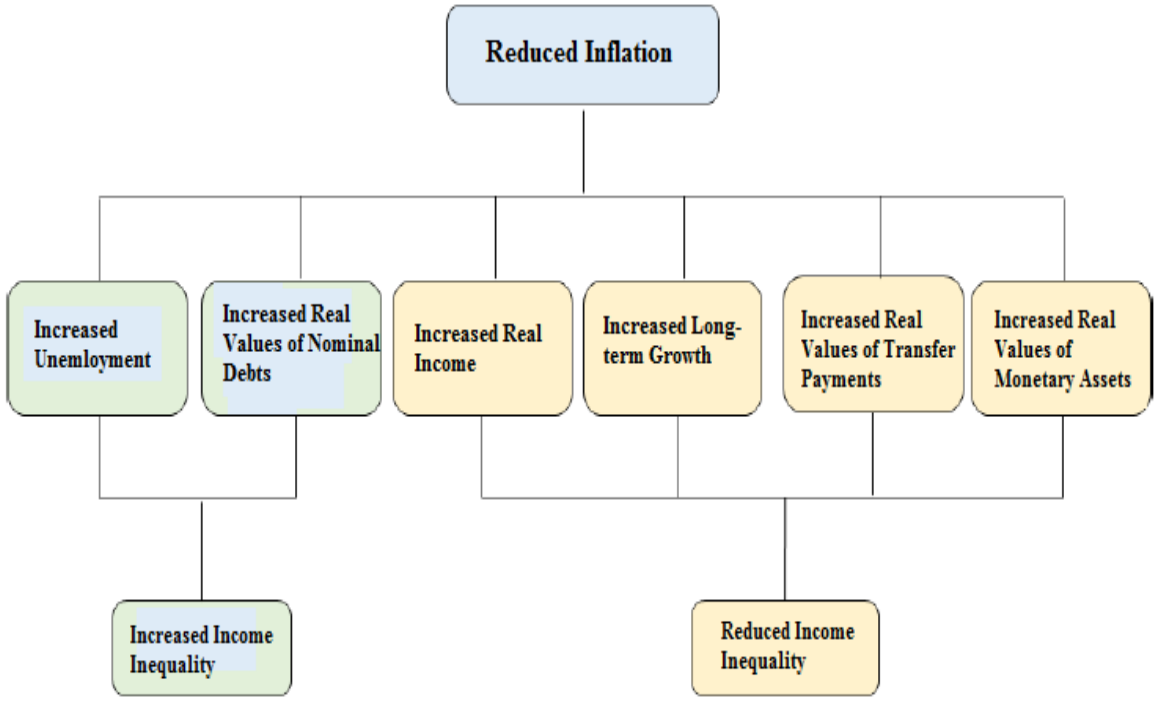

Fig. 1: The dual effects of long-term inflation on income inequality [48]

Considering the above-mentioned, the net effect of inflation on income inequality seems to be ambiguous in the long term. In this respect, Galli [48] believed that the net effect of inflation on income inequality in the long term depends on the initial inflation rate. When the inflation rate is high, a reduction in the inflation rate can reduce income inequality through its positive effects. On the other hand, when the inflation rate is low, the distribution benefits of inflation may be small, while inflation and unemployment are more likely to encounter, which would worsen income inequality [41]. Additionally, a high inflation rate influences the decisions of production and financial institutions. It encourages economic agents to attempt to obtain inflation-induced rents rather than attempting to raise their income by raising their institutions' productivity. Capital profitability arising from inflation adversely impacts not only the behavior of economic agents but only the inter-time allocation of resources. When there are monopoly and influence centers along with inflation, the profitability of unproductive activities and rent-seeking activities increases. Thus, resources are allocated to activities that provide significant profits to specific individuals rather than they are allocated to job-creating activities that can play an essential role in income distribution improvement. This worsens income distribution [22]. Fig. 2 illustrates how inflation impacts inequality by enhancing rent activities.

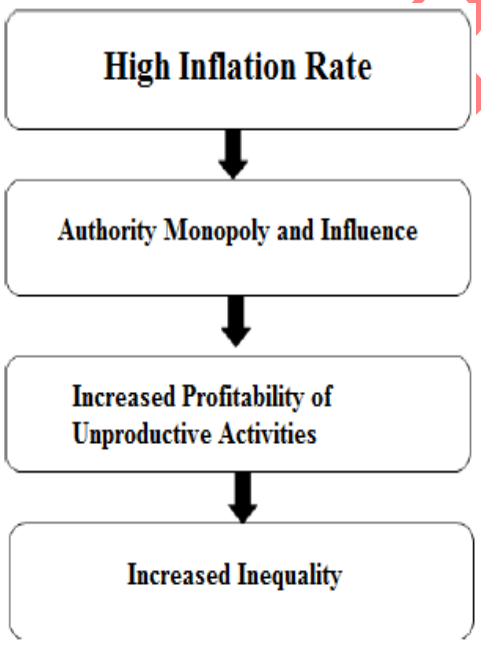

Fig. 2: The impact of inflation on inequality by enhancing rent activities [22]

Scholtz proposed another relationship route between inflation and inequality. They concluded that when product prices change in response to changed production factor prices and wages (i.e., pressure-cost inflation), a change in prices can reduce the contribution of interests to income inequality. However, when demand for the final product changes the price level (i.e., pressure-demand inflation), and wages are determined on nominal bases, the contribution of profits increases in the same direction as price changes, which increases income inequality. This is related to the Philips curve. According to A.W. Philips, a rise in demand reduces the unemployment rate but increases the wage growth rate and inflation rate. Then, as money illusion declines, the unemployment rate and inflation rate rise. Fig. 3 represents the impact of demand pressure-induced inflation on income inequality.

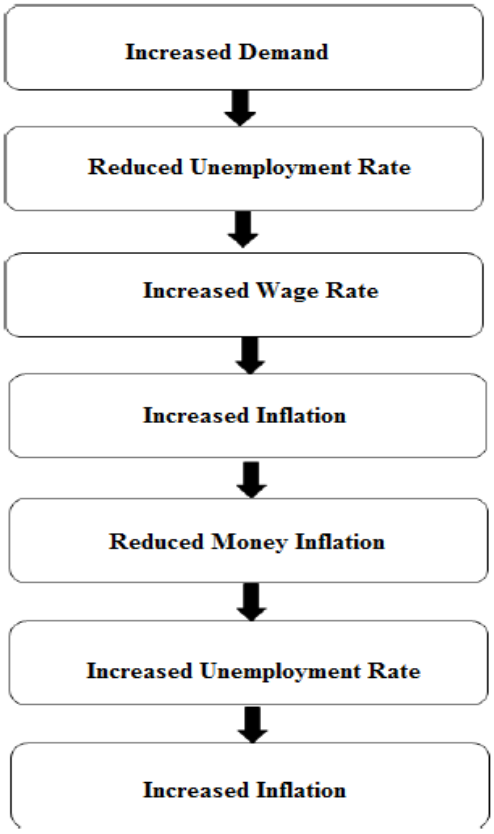

Fig. 3: The impact of demand pressure-induced inflation on income inequality

3 Literature Review

Different studies have investigated the determination of the optimal inflation rate and the effects of a change in the optimal inflation in macroeconomic variables. Some studies incorporated the minimization of welfare costs, while some others included the minimization of income inequality. Table 1 provides Iranian studies, while Table 2 represents non-Iranian studies.

Table 1: Iranian studies

Authors	Year	Model	Results
Farahmand-manesh and Armanmehr [20]	2018	The linear expense system and the Atkinson index	A dramatic rise in prices (high inflation) increases inequality. Also, among the influencing factors, inflation has the largest impact on the creation of income inequality (~48%)
Golkhandan [23]	2016	Smooth transition regression (STR) model	Inflation non-linearly influences income inequality in the long term. The inflation rate affects income inequality in the form of a dual-regime structure in which one regime has negative effects, while the other one has positive effects.
Jalali [11]	2016	Atkinson welfare function	The findings indicated that poor classes suffered from inflation pressure more than non-poor classes before 2011. The results were not the case for the period after 2011.
Mirbagheri Hayyer and Shokuhifard [25]	2016	Panel data	A rise in inflation diminished purchasing power and increased Gini coefficient and inequality in Islamic countries

Table 1: continue

Bakhshi Dastjerdi and Sheykh Ansari [6]	2015	Code optimization	The inflation rate that can provide the maximum social welfare to the economy of Iran was found to be 1.96%.
Eslami [1]	2014	Cointegration method	A rise in the domestic per capita gross production and inflation rate enhances the income gap in society, and a rise in per capita subsidy, per capita employment, and per capita wealth tax decreases the income gap.
Hadian and Izadi[39]	2014	Threshold regression	The optimal inflation rate of the economy of Iran was found to be 5.5%.
Komeyjani and Mohammadzadeh [21]	2014	Apparently-unordered regression	Inflation, unemployment, government expenses, and the ratio of 10% high-income class to 10% poor negatively impact inequality, and a rise in the subsidies of basic goods and the contribution of 40% poor improves inequality. The results indicated that a rise in inflation, unemployment, basic goods subsidies, and the ratio of 10% wealthy to 10% poor benefits high-income classes, leading to enhanced inequality. Also, a rise in the contribution of 40% poor benefits low-income classes, leading to reduced inequality.
Shakeri et al. [165]	2013	The Toda and Yamamoto approach	There is a nonlinear relationship between inflation and income inequality in Iran.
Zaeri and Nadri [13]	2013	Bailey's partial-equilibrium model	The mean inflation welfare cost and nominal interest rate were estimated to be 3.54 and 1.42, respectively.
Ebadatian et al. [18]	2012	Bailey's surplus welfare criterion and Lucas's compensating variation	The optimal inflation rate was obtained to be 1% and 3% by Bailey's and Lucas's methods at the highest inequality avoidance level in Iran, respectively.
Nazari and Mazaheri [26]	2011	Vector autoregression	The hypothesis of a U-shaped relationship between inflation and income distribution was not supported.
Tashkini and Afzali [7]	2011	SVAR method	Housing is a stable component of inflation in the economy of Iran, and it is consistent with expectations. Also, the momentums of basic inflation, import price, and non-basic inflation explained 40% and 6% of inflation variance, respectively.
Kafaei and Moradbeigi [28]	2010	Descriptive analysis and wealth-oriented gap	The findings revealed an inflation inequality between rural and urban regions in time periods. Inequality fluctuated over time. However, it was higher in urban regions than in rural regions. In addition, inequality has increased in recent years, making it necessary to put in place specific policies for different regions, including rural and urban regions, and for provinces.
Abounouri et al. [3]	2010	Ordinary most squares	Inflation and unemployment pose larger impacts on Gini coefficient urban regions than in rural regions in Iran.
Hadizonouz [24]	2010	Analytical	The government should apply the required structural reforms in its structure in order to make and execute policies for economic growth and social justice
Zibaei [14]	2005	Linear regreion	An increase in inflation and unemployment not only does not improve income distribution but also functions as a descending tax that worsens income distribution.
Abounouri [2]	1997	Iteratively reweighted least squares	A 1% rise in the inflation rate brought a 6% increase in the expense inequalities of households in the next period.
Asgari [19]	1991	Simple dual-variate regression	The results indicated the negative impact of inflation on the maximum income gap, while no significant relationship was observed between inflation and the Gini coefficient. Also, an inverse significant relationship was found between inflation and the contribution of 10% poor class.

Table 2: Non-Iranian studies

Authors	Year	Model	Results
Deyshappriya [40]	2016	Panel data analysis	It was recommended to maintain price stability for keeping income distribution with higher income and low income inequality.
Menna and Tirell [30]	2016	Dynamic stochastic general equilibrium (DSGE)	When the contribution of limited factors was measured for adaptation to Gini index in USA, the satisfactory inflation rate was obtained to be above 4%.
Monnin[41]	2014	Panel data analysis	There was a U-shaped relationship between inflation and income inequality in OECD countries; a rise in inflation to 13.3% reduced income inequality. At inflation rates above 13.3%, a rise in the inflation rate increased income inequality.
Thalassinos et al. [42]	2015	Panel data analysis	Inflation had a positive and significant effect on income inequality in European countries.
Hitoshi et al.[43]	2008	DSGE	The optimal inflation rate was estimated to be 0.5-2.0% in different cases. This range varies, depending on assumptions and parameters.
Amornthum	2004	Threshold regression	Adding the second-order term of filtered inflation to the model not only increased the model's significance but also created a U-shaped relationship between inflation and income inequality in the studied countries.
Bulir[44]	2001	Panel data analysis	Inflation nonlinearly impacted inequality.
Galli et al. [48]	2001	Panel data analysis	There was a U-shaped relationship between inflation and inequality. The minimum estimated inequality was obtained to be 6% and 12% for the USA and OECD countries, respectively.
Parker[47]	1998	Multivariate regression	Inflation increases income inequality if fixed wages such as pension payments are not adjusted in proportion to inflation.
Bulir[45]	1998	Kuznets Model	A rapid reduction in inflation created a significantly lower income distribution inequality. Also, it was found that a further decrease in inflation to very low levels increased inequality.
Bulir and Gulde[46]	1995	Extended model	The results supported the Kuznets hypothesis and the destructive impact of increased inflation, changes in inflation, and changes in the nominal exchange rate on income distribution.

4 Hypotheses

Based on Hitoshi et al. [43] and theoretical foundations, the following hypotheses were made:

Hypothesis 1: The optimal inflation rate can be measured by the dynamic stochastic general equilibrium (DSGE) model

Hypothesis 2: A reduction in the inflation rate to below the optimal inflation rate while other factors are fixed increases income inequality

Hypothesis 3: A rise in the inflation rate while other factors are fixed increases income inequality

Hypothesis 4: Income inequality is minimized at the optimal inflation rate

5 Methodology and Model

This study employs DSGE models due to their particular advantages. Such models offer various advantages, which makes them interesting and beneficial for analyzing macroeconomic policies. The DSGE structure is one of such advantages, i.e., each equation has an economic interpretation in the model. In addition, such models have microeconomic bases and are extracted by optimizing the behavior of households and institutions in the economy. As another feature of DSGE models, they are stochastic. Thus, they consider the fact that the economy is influenced by stochastic shocks, analyzing the

impacts of such shocks on the economy. Such features have made DSGE models of interest and effectiveness for analyzing different macroeconomic policies' impacts.

5.1 Shocks in the Model

In the proposed model, the general relationships between the main components, including households, institutions, the government, the central bank, and the external world, are explained. Then, details are provided in proportion to the relationships' types. The Model's shocks include

A) Supply-side shocks (workforce productivity),
B) Demand-side shocks (investment preferences and government expenses) (Government demand G, as a component of the total demand, causes demand-side shocks), and
C) Money shocks (the interest rate and other targeted variables). Money shocks typically follow a first-order autoregression process.

Once the DSGE models are specified, two important conditions should be met for equilibrium: 1) brokers should perform optimization, and 2) markets, including the goods market and work market, should be cleared. Fig. 4 shows the shocks included in the model [17].

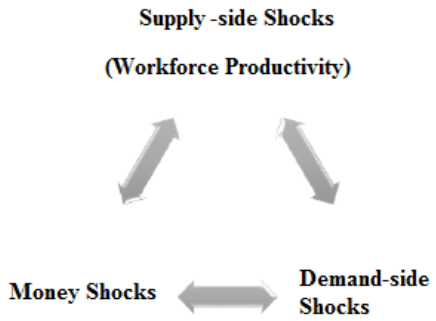

Fig. 4: The DSGE model's shocks [50]

Households are consumers and make decisions between consumption and investment. Workforce supply is performed only by this component. The income of households comes from three sections, including workforce supply, intermediary goods production institutions' profits, and receiving government transfer payments. They maximize the current value of their expected utility. Finally, their expenses are purchasing final goods and services and paying taxes to the government.

5.2 Specifying the DSGE model for the economy of Iranian

A) Household

In the proposed economy, population and households with unlimited horizons are assumed to be present. Moreover, consumed purchases are assumed to the same as the total costs of transactions.

$$S_t^i = c_{t.i} s\left(\frac{P_{t.i}\, C_{t.i}}{M_{t.i}}\right).\ s'\left(\frac{P_{t.i}\, C_{t.i}}{M_{t.i}}\right) > 0\ for\ \frac{P_{t.i}\, C_{t.i}}{M_{t.i}} >\ v_i^* \qquad (1)$$

where $v_i = \frac{c_{t.i}}{m_{t.i}}$ is the money circulation rate, $m_{t.i.} = \frac{M_{t.i}}{P_{t.i}}$ is the real money equilibrium, $M_{t.i}$ is the nominal money amount, $C_{t.i}$ is individual consumption, S_t^i is the transaction cost, and $P_{t.i}$ is the consumer price level. Schmitt-Grohé and Uribe (2004) formulated the transaction cost as

$$s\left(\frac{P_{t.i}\,C_{t.i}}{M_{t.i}}\right) = A\,\frac{P_{t.i}\,C_{t.i}}{M_{t.i}} + \frac{B}{\frac{P_{t.i}\,C_{t.i}}{M_{t.i}}} - 2\sqrt{AB} \tag{2}$$

Households are consumers and make decisions between consumption and investment. Workforce supply is performed only by this component. The income of households comes from three sections, including workforce supply, intermediary goods production institutions' interests, and receiving government transfer payments. They maximize the current value of their expected utility. Finally, their expenses are purchasing final goods and services and paying taxes to the government. The utility function of the entire of a household is

$$\mathrm{U}=\sum_{t=0}^{\infty}\beta^t\,u(c_t^i\,.\,l_t^i); \qquad u\left(c_t^i.\,l_t^i\right) = ln\,c_t^i + \eta\ln\,(1-l_t^i) \tag{3}$$

in which $\beta \in (0,1)$ is the interperiod discount rate, c_t^i is consumption, l_t^i is the working hours, and $\mu_w > 1$ is the steady-state markup wage. Each household offers a distinct workforce.

B) Labor market

Workforce demanders receive different workforce services from households and produce different products. Such institutions function in a complete competition state. They solve the household income maximization problem as

$$\begin{aligned} &\max\ w_t l_t^d - \int_0^1 w_t^i l_t^i di \\ &\text{s.t.} \\ &l_t^d = \left(\int_0^1 l_t^{i^{pw}} di\right)^{\frac{1}{pw}} \end{aligned} \tag{4}$$

The workforce demand function is calculated as

$$l_t^i = l_t^d\left(\frac{w_t^i}{w_t}\right)^{\frac{1}{pw-1}} \tag{5}$$

The wage index is calculated as

$$w_t = \left(\int_0^1 (w_t^i)^{\frac{pw}{pw-1}}\,di\right)^{\frac{pw-1}{pw}} \tag{6}$$

The following equation indicates that the same workforce with the same working hours receive the same wages. Thus, Eq. (6) is rewritten as

$$w_t = [(1-\theta)(w_t^u)^{\frac{pw}{pw-1}} + \theta(w_t^c)^{\frac{pw}{pw-1}}]^{\frac{pw-1}{pw}} \tag{7}$$

Similarly, the workforce demand equation can be rewritten as

$$l_t^d = [(1-\theta)(l_t^u)^{pw} + \theta\,(l_t^c)^{pw}]^{\frac{1}{pw}} \tag{8}$$

C) Consumers

Households are assumed to have a bank and a brokerage account. In the bank account, they receive balances and money payments for their wages. In the brokerage account, on the other hand, they keep other types of wealth. Consumption decisions on money transactions can only be made by withdrawing money from the bank account. Money is transferred between two accounts in N periods, such that only 1/N of the balance can be withdrawn in each period. For a p_t, the bank account is written as

$$c_t^u(p_t) + s_t^u(p_t) + m_t^u(p_t) = (1-\tau_t)w_t^u l_t^u + \frac{m_{t-1}^u(p_t)}{\pi_t} - \frac{\xi_w}{2} l_t^u\left(\frac{w_t^u\,\pi_t}{w_{t-1}^u} - 1\right)^2 + x_t(p_t) \tag{9}$$

where τ_t is the income tax, $\pi_t = \frac{p_t}{p_t - 1}$, ξ_w is the standard nominal wage adjustment cost, and $x_t(p_t)$ is the amount transferred from the brokerage and bank accounts. The brokerage account is represented as

$$k_t(p_t) + b_t(p_t) = \{(1-\tau_t)\left(r_t^k k_{t-1}(p_t)\right) + (1-\delta_t)\left(k_{t-1}(p_t)\right) + (\tau_t \delta)\left(k_{t-1}(p_t)\right) + d_t + \frac{R_{t-1} b_{t-1}(p_t)}{\pi_t} - x_t(p_t) \quad (10)$$

in which d_t is the real interest of the institute, R_t is the nominal interest rate, b_t^u is the real amount of a riskless bond that pays a money unit in period $t+1$, r_t^u is the real capital lease rate, k_t^u is the non-issued shares, and δ is the depreciation rate. In Eq. (10), it is assumed that $c_t^u(p_t) \geq 0$, $M_t^u(p_t) \geq 0$, $k_t^u(p_t) \geq 0$, and $l_t^u \epsilon [0,1]$. The standard Ponzi-less conditions for bond aggregation is assumed to be

$$\lim_{T \to \infty} \beta^{T-t} b_T^u(p_t) \geq 0 \quad (11)$$

The first-order condition of the consumer equation is

$$\lambda_t^c = \frac{u_c\left(c_t^i, l_t^i\right)}{1 + s\left(\frac{c_t^c}{m_t^c}\right) + \frac{c_t^c}{m_t^c} s'\left(\frac{c_t^c}{m_t^c}\right)} \frac{\left(W_t^c \rho_w + \frac{u_c\left(c_t^i, l_t^i\right)}{(1-\tau_t)\lambda_t^c}\right)\left(\frac{W_t^c}{W_t}\right)^{\frac{1}{P_w - 1}}}{1 - P_w}$$
$$+ \xi_w \frac{w_t^c \pi_t}{w_{t-1}^c}\left(\frac{w_t^c \pi_t}{w_{t-1}^c} - 1\right) = \beta\left[\frac{l_{t+1}^c \lambda_{t+1}^c}{l_t^c \lambda_t^c} \xi_w \left[\frac{w_{t+1}^c \pi_{t+1}}{w_t^c}\left(\frac{w_{t+1}^c \pi_{t+1}}{w_t^c} - 1\right)\right]\right] \quad (12)$$

and

$$1 - \left[\frac{\beta}{\pi_{t+1}} \frac{\lambda_{t+1}^c}{\lambda_t^c}\right] = s'\left(\frac{c_t^c}{m_t^c}\right)\left(\frac{c_t^c}{m_t^c}\right)^2 \quad (13)$$

The household money demand is a negative function of the expected inflation and is a positive function of the final predicted wealth utility rise.

D) Intermediary institutions

Intermediary institutions produce distinct products. Product z is produced under the Cobb–Douglas production function and the following descending demand function:

$$y_t(z) = l_t(z)^a k_{t-1}(z)^{1-a} \quad (14)$$

$$y_t(z) = y_t^d \left(\frac{p_t(z)}{p_t}\right)^{\frac{1}{p-1}} \quad (15)$$

$$\frac{\xi_p}{2} y_t^d \left(\left(\frac{p_t(z)}{p_{t-1}(z)}\right) - 1\right)^2 \quad (16)$$

where ξ_p is the price stickiness size. The re-optimized cost is assumed to be a fraction of income. In a symmetric equilibrium, the adjusted price is written as

$$\frac{p - mc_t}{1 - p} + \xi_p \pi_t(\pi_t - 1) = \beta\left[\frac{y_{t+1}\lambda_{t+1}^u}{y_t \lambda_t^u} \xi_p [\pi_{t+1}(\pi_{t+1} - 1)]\right] \quad (17)$$

in which mc_t is the real final cost. To minimize the cost, the two following equations are required:

$$w_t = \alpha mc_t \left(\frac{l_t}{k_{t-1}}\right)^{\alpha - 1} \quad (18)$$

$$r_t^k = (1-\alpha) mc_t \left(\frac{l_t}{k_{t-1}}\right)^{\alpha} \tag{19}$$

where $\frac{1}{\rho} = \mu^p$, and it is obtained under floating prices. The institution interest is calculated as

$$d_t = l_t^a k_{t-1}^{1-a} - w_t l_t^d - r_t^k k_{t-1} - \frac{\xi_p}{2} l_t^a k_{t-1}^{1-a} (\pi_t - 1)^2 \tag{20}$$

E) Final producing institutions

Institutes producing the final products purchase different goods from intermediary institutions and produce a final product. The final product could be used by private or public consumers for investment. Such institutions function in a complete competition state based on the following maximization equation:

$$\max P_t y_t^d - \int_0^1 p_t(z)\, y_t(z) dz$$

s.t.

$$y_t^d = \left(\int_0^1 y_t(z)^p \, dz\right)^{\frac{1}{p}} \tag{21}$$

where y_t^d is the final product. The first-order optimal condition is met as

$$p_t = \left(\int_0^1 p_t(z)^{\frac{p}{p-1}} dz\right)^{\frac{p-1}{p}} \tag{22}$$

F) Government budget

The government supplies a counter-productive and exogenous amount of general goods. It satisfactorily selects an income tax rate and a nominal interest rate to provide exogenous costs. Given the government's selected income tax rate and nominal interest rate, money growth and inflation are determined based on balanced competition conditions. The government's debt should provide the budget limitation as

$$R_{t-1} \frac{b_{t-1}}{P_t} + g_t = \tau_t \left(w_t l_t^d + r_t^k k_{t-1}\right) - \tau_t \delta k_{t-1} + \frac{M_t - M_{t-1}}{P_t} + \frac{b_t}{P_t} \tag{23}$$

in which g_t is the final product.

G) Summarizing the equations

The equations and the total consumption, total working hours, total real money balance, bonds, interests, total capital, and total production are summarized as

$$c_t = (1-\theta) c_t^u + \theta c_t^c \tag{24}$$

$$m_t = (1-\theta) m_t^u + \theta m_t^c \tag{25}$$

$$b_t^u = \frac{b_t}{(1-\theta)} \tag{26}$$

$$d_t^u = \frac{d_t}{(1-\theta)} \tag{27}$$

$$k_t^u = \frac{k_t}{(1-\theta)} \tag{28}$$

and (29)

$$y_t^d = (1-\theta)c_t^u + (1-\theta)S_t^u + \theta c_t^c + \theta S_t^c + k_t + (1-\delta)k_{t-1} + g_t + \frac{\xi_w}{2} y_t (\pi_t - 1)^2 + (1-\theta)\frac{\xi_w}{2} l_t^u \left(\frac{w_t^u \pi_t}{w_{t-1}^u} - 1\right)^2 + \theta \frac{\xi_w}{2} l_t^c \left(\frac{w_t^c \pi_t}{w_{t-1}^c} - 1\right)^2$$

respectively.

H) Measuring income inequality

The Gini coefficient formula is employed to measure income inequality as

$$lneq_t = \frac{1}{n}\left[n + 1 - 2\left(\frac{\sum_{t=1}^{n}(n+1-i)Y_{i.t}}{\sum_{t=1}^{n} Y_{i.t}}\right)\right] \quad (30)$$

where $Y_{i.t}$ is the income of household *i*, *n* is the number of households, and *i* denotes the household.

5.3 Solving DSGE models

To empirically solve DSGE models, one should focus on achieving approximate solutions after obtaining the main equations since such equations are typically nonlinear. In this respect, there are a number of approximations, including the Log-Linear Approximation Method. Hence, a common procedure for solving nonlinear DSGE models is as follows:

1) Determining the main equations, including those obtained by extracting the first-order optimization conditions of economic brokers, market-clearing constraint equations, and stochastic shock equations,
2) Determining the steady state of the model's main equations,
3) Determining the log-linear forms of the main equations based on the steady state by using methods such as the Taylor series and the method of Uhlig,
4) Calibrating the parameters and estimating the model by the Bayesian method, and
5) Replacing the estimated data in the model and obtaining reaction functions.
6)

5.4 Data collection methods

Optimizing the objective functions of the above-mentioned brokers, the result of the obtained economic relations is a system of linear difference equations. In the present study, the equations are calculated by the log-linear method of Uhlig. The log-linear process is based on the Taylor series. Before introducing the method, it is required to provide some relations. Assume that Xt is a variable, X is its stable value, and X is the variable's logarithmic deviation from the stable value. Then, it can be obtained by using the first-order Taylor series. It should be noted that it is necessary to determine and calibrate parameters that do not need to be estimated, such as the stable values of parameters, before estimating parameters. For this purpose, other researcher's findings in microeconomics and macroeconomics are typically employed. For example, the discount factor and depreciation rate are selected based on the model solving conditions. Some parameters are valued based on previous studies, such as the capital adjustment cost, price adjustment cost, and the adjustment cost of debts to the central bank. On the other hand, some other parameters, such as monetary policy variables' weights, are calculated by Eviews based on the defined behavior function. Then, the parameters are estimated by using the Bayesian method. To estimate other parameters, it is required to determine the previous distributions, means, and standard deviations of the parameters. By considering initial values for the means and standard deviations of the parameters, the parameters can be estimated by using the Bayesian method. It should be noted that the

previous distributions of the parameters are chosen based on the features of the parameters and intended distribution features.

6 Findings

Fig. 5 shows the inflation rates and Gini coefficient variations of Iran in the last 20 years. As can be seen, the Gini coefficient of Iran increased in some years and reduced in some other years. Gini coefficient tends to increase in a time interval as the general price level growth declines. The inflation rate reduced to 10% in 2009, following which the reducing trend of the Gini coefficient becomes an increasing trend in the next years.

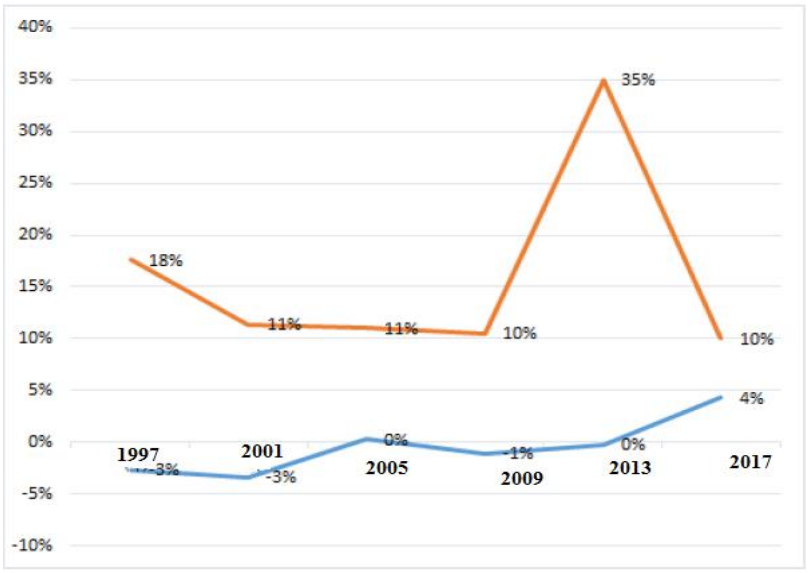

Fig. 5: The inflation rates and Gini coefficients of Iran in the past 20 years (Statistical Centre of Iran, 2018)

Fig. 6 illustrates the Gini coefficient chart of Iran in the last 20 years. As can be seen, the Gini coefficient was high in the last years and underwent a considerable rise in the past 4 years. Moreover, Fig. 7 demonstrates the real interest rate in Iran in the past 20 years.

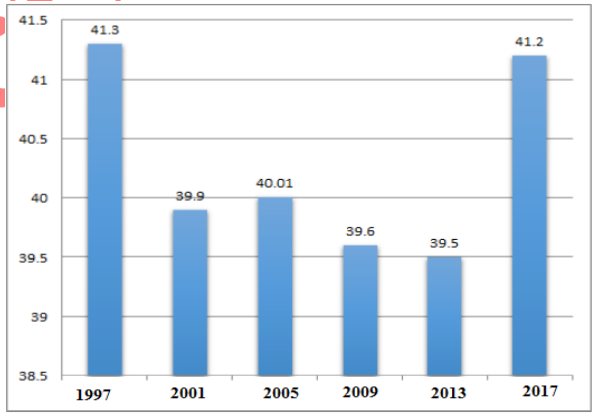

Fig. 6: The Gini coefficient of Iran in the past 20 years (Statistical Centre of Iran, 2018)

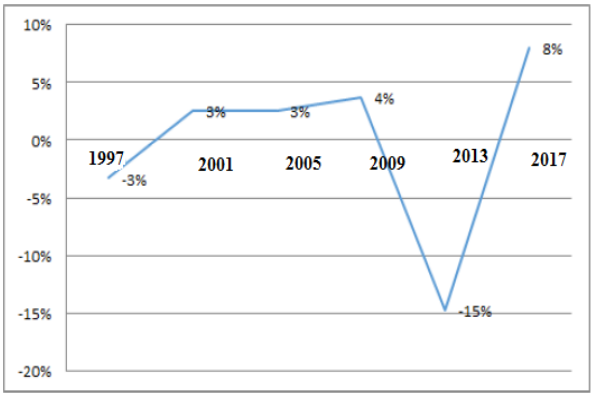

Fig. 7: The Real interest rate in Iran in the past 20 years (Central Bank of the Islamic Republic of Iran, 2018)

As can be seen, the real interest rate (i.e., the difference between the interest rate and inflation rate) was both negative and positive in the past year. Thus, the Gini coefficient does not report satisfactory income distribution in years with negative and small real interest rates.

6.1 Model calibration

The parameters' values were selected based on Iranian and non-Iranian references and Dastjerdi and Sheykhansari [6], as shown in Table 3.

Table 3: The parameter values

Parameter	Value	Reference	Parameter	Value	Reference
Inverse repository elasticity	2.24	Tavakolian[9]	Population growth rate	0.0129	Statistical Center of Iran
Inverse inter-period consumption replacement	1.5	Hajikhodazadeh [10]	Depreciation rate	0.042	Amini and haji [5]
Significance ratio of cash reserves to consumption	1	Most economic studies	Mean legal reserve	0.15	Central Bank of the Islamic Republic of Iran
Time preference rate	0.02	Romer [31]	-	-	-

The results suggest that the inflation rate that can impose the minimum income inequality is 3.72%. A rise or a reduction in this inflation rate decreases the Gini coefficient. Fig. 8 represents the instant reaction function. When a shock as large as the standard deviation is applied by the optimal inflation rate to the Gini coefficient, inequality rises, and then the shock disappears. Such a shock can arise from revision in the government's policies in the initial or end years (based on the political economy). The optimal inflation rate can be increased by a standard deviation unit by changing the monetary authority policies based on changing macro-variable priorities, such as improving employment. A positive shock from the optimal inflation rate increases the inflation of the current and upcoming years and reduces the real wage rate and real lease. The reduced real compensation increases investment demand and workforce demand, which enhances production. However, the inflation caused by such a shock cannot last long. This, the monetary policy-makers have to adjust their policy toward inflation reduction. Thus,

the money amount declines, and the impacts imposed on other variables will be the same as the contract (anti-inflation) policy.

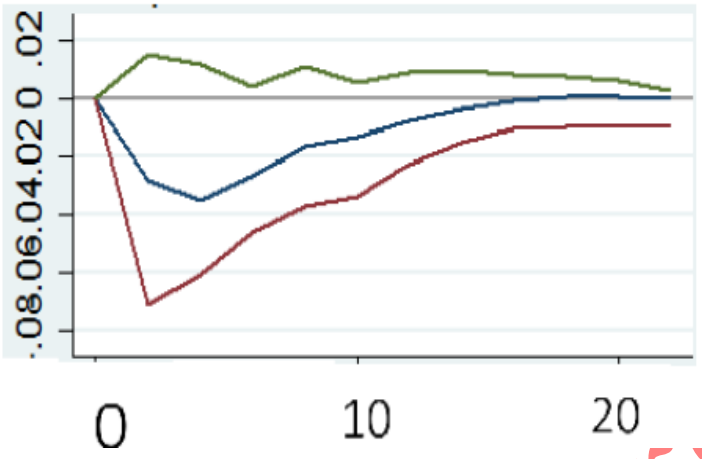

Fig. 8: The inequality reaction due to the target inflation-caused shock

7 Conclusions

Although the price mechanism and its flexibility and fluctuations are the most effective factors in optimally allocating factors and serve as links between consumers' demand and economic institutions' production programs, changes in the general price level play an essential role in raising inequality. The present study was conducted to determine the optimal inflation rate in order to minimize income inequality in Iran during 1997-2017. The DSGE results proposed the inflation rate that could impose the minimum income inequality to be 3.74%. A rise or a reduction in this rate would reduce the Gini coefficient. The government should realize the minimum inequality through reduced inflation by decreasing intervention in the economy, observing the monetary rule, and managing the liquidity growth rate. In addition, according to the quantity theory of money, increased production can increase the gross domestic production and national revenue and reduce inflation. In turn, reduced inflation can lay the ground for economic growth and production rise, decreasing class distinction. Transferring income from high-income classes to low-income classes by paying subsidies is another factor with a significant effect on inequality reduction. Policy-makers should plan for and target the entire macroeconomic variables, including liquidity growth, government expenses, employment, and inflation to improve public welfare and minimize income inequality.

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