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# Reviewing the Impact of Monetary Policy on Income Distribution in Iran Using Genetic Algorithms (GA) and Particle Swarm Optimization Algorithm (PSO)

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## Abstract

Inequality in income distribution is the source of injustices such as class differences based on wealth, incomes, and consumption among members of society. Achieving fair distribution of income requires the proper use of economic instruments among which monetary policy is the most important tool. In this study, using annual data from 1979-2013, the effects of liquidity volume (monetary policy index) on inequality of income distribution (using Gini coefficient inequality index) have been addressed. Therefore, Gini coefficient function was estimated with particle swarm optimization algorithm and genetic algorithm. And based on performance assessment criteria, the model with particle swarm optimization algorithm was chosen to study the impact of monetary policy on income distribution in Iran. Research results show that the relation of liquidity volume variable with direct income distribution and the relation of government expenses with income distribution are significant and indirect. Also, the results show that by increasing human development index, income inequality in society increases and rising inflation reduces inequality of income distribution.

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## Introduction

Poor distribution of income, followed by poverty, is a topic that economists concern about more than wealth. Today, the importance of income distribution in society is to the extent that almost all economists consider income distribution as one of the objectives and tasks of government (Assari et al, 2009). For this reason, this goal is pursued by all countries, especially underdeveloped countries. Today, eliminating disparities, injustices, and adverse economic, social, and political effects resulting from inequality in income distribution and improving income distribution is followed as an important goal for the country's economic policy. Therefore, achieving an equitable distribution of income requires the proper use of economic tools. Monetary policy can be named as one of the most important tools. Monetary policy is a concept or a general understanding of the capabilities and power of monetary authority and its impact on the main economic variables. Although the main task of this institution is to control price level, holding the level of economic activities high and supporting the national currency, are considered other main duties. Monetary policy by central bank intervention and through changes in aggregate demand, transfers its effects to the economy. So, reviewing what is the impact of monetary policy on income distribution and poverty is important.

Today, due to the complex issues and importance of achieving answer more quickly, other classic methods cannot solve some problems, so that the use of evolutionary algorithms and meta-heuristic algorithms has been increased in recent years.

Genetic Algorithm is one of the most efficient optimization methods in this area. Genetic Algorithm was first proposed by Holland in 1975. This algorithm is part of Darvin' Evolutionary Computation Theory which nowadays its application as part of artificial intelligence in different sciences is rapidly expanding. Particle Swarm Optimization algorithm for the first time was introduced by Kennedy and Eberhart in 1995 inspired by behavior of birds and fish. This powerful algorithm is based on physiology of effects and social learning. Functionally, these two algorithms are the best methods for optimizing problems. Therefore, these algorithms can be used in estimating and predicting the future trend of intended variable. The purpose of this paper is to examine the impact of monetary policy on income distribution in Iran. Accordingly, this paper is divided as follows. In the second section, the literature review is provided and in the third section, theoretical foundations are presented. Then, in the fourth section, the model will be estimated using Genetic Algorithm (GA) and Particle Swarm Optimization Algorithm, and using performance evaluation criteria, estimated model will be chosen with superior algorithm and finally, conclusion will be presented.

## Literature Review

In this section, a summary of the studies related to the effects of monetary policies on income distribution is provided.

Parvin and Taheri fard (2007) have examined the impact of monetary policies on poverty and income distribution. Investigating the relationship between monetary policy variables and poverty and inequality indices in this study through regression relations supports this hypothesis that monetary policy doesn't act to reduce poverty. These results can be attributed to inflationary nature of monetary policies and the impossibility of effectiveness of money supply on investment and employment.

Assary et al (2009) have investigated the impact of monetary policies on income distribution in Iran. Research results using a VAR model show that increasing the money volume as a measure of monetary policy, doesn't immediately increase income inequality. But from the second year, the exacerbating effects of expansionary monetary policy begin and continue in later periods.

Galli & Hoeven (2001) in reviewing inflation monetary policies on income inequality both theoretically and empirically found that in countries with high inflation, contractionary monetary policies are more effective in reducing inequality, this is while reducing inflation in economies with low inflation might increase inequality. His experimental study in the United States and 15 countries of OECD has supported this hypothesis.

Davtyan (2015) has studied the relationship between monetary policy and income distribution. In this paper, the effects of monetary policy on income distribution in the United States are reviewed. The results show that contractionary monetary policy reduces income inequality. In contrast, if contractionary monetary policy doesn't include over one percent of distribution, increases income inequality.

## Model Clarification

### *Gini Coefficient Model*

This section, divided into two parts, reviews the theoretical relationship between income distribution, the price of factors of production and distribution of ownership. In the first part, a model of closed economy is described. In part two, this framework is generalized to the world consists of several economies which have the same functions of production and preferences and finally, is discussed around the impact of trade on personal income distribution.

In the closed economy assumption, there are M different production function and N subject. E vector shows the total inventory of economy factors of production and vector $Q^c$ shows total production. Factors of production for production of goods $Q^c$ are used through production function *F*.

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$$Q^c = f_{(E)} \qquad (1)$$

*F* shows production functions vector. If there is complete competition in the market of factors and final goods, the price of each factor is equal to the value of final production in any part in which production factor is used.

$$P^c F'_{(E)} = W^c \qquad (2)$$

$P^c$ is the final goods price vector in a closed economy, $F'_{(E)}$ is the final production of factors vector E and $W^c$ is the factors price vector. In addition, it is assumed that there is full employment for all factors. Full employment terms and equation (2) specifies factors price with respect to the price of goods $P^c$ and relative inventory of factors of economy *E*:

$$W^c = W_{(E, P^c)} \qquad (3)$$

The system is closed with the demand for the final goods:

$$P^c = P_{(Q^c)} \qquad (4)$$

By putting equations (1) and (4) in equation (3), factors price will be obtained as a function of factors of production inventory:

$$W^c = W_{(E)} \qquad (5)$$

Inventory of factors fully specifies factors of production price in a closed economy. The point is that if production functions F have constant returns to scale, the size of economy doesn't determine the relative price of factors of production. In addition, the relative price of factors has inverse relation with their frequency under the assumption of diminishing returns to scale and the absence of a complementary relationship between factors.

In a small open economy, the global prices vector $P^*$ specifies the domestic price of tradable goods. Under the following conditions, international trade can also determine the factors price: 1) economy is sufficiently similar to the rest of the world with respect to inventories; 2) economy has a technology like the rest of the world, 3) there aren't non-tradable goods, 4) there are factors of production as goods, 5) homogeneous production functions are of degree one, 6) there isn't the phenomenon of intensity return of factors of production. If all of above conditions are met, there is equalization of factors price and factors price in the country will be determined by global commodity price:

$$W^o = W_{(P^*)} \qquad (6)$$

If any of the conditions listed above fails to remain, the convergence of factors price will not be decisive and both international price of goods and factors of production inventory inside the country determine the price of domestic production factors:

$$W^{o}=W_{(P^{*}, E)} \tag{7}$$

In an integrated global economy which countries' factors of production inventory aren't so different, international prices are determined by the relative inventory of world's factors of production:

$$P^{*}=P^{*}_{(E^{*})} \tag{8}$$

By replacing the equation (8) in the equations (6) and (7), following equations will be obtained:

$$W^{o}=W^{o}_{(E^{*})} \quad , \quad W^{o}=W^{o}_{(E^{*},E)} \tag{9}$$

These equations express that factors price is determined by international inventory of factors, if assumptions (1) to (6) are proved and factors price affects price of goods inside the country under more general modes of factors inventory. There is almost no country in the world without tariffs. When governments intervene and impose tariffs and other barriers to trade, equalization of price of factors doesn't occur. *T* is called deviation of global price of factors. So, equation (9) becomes as follows:

$$W^{o}=W^{o}_{(T, E^{*},E)} \tag{10}$$

The relationship between income distribution of factors and distribution of personal income is ownership structure. Everyone obtains his/her income from several factors of production so that the total income of individual $i$ ،$Y_i$:

$$Y_i = W_{1(T, E^{*},E)}E_1W_{i1} + \ldots + W_{j(T, E^{*},E)}E_jW_{ij} \quad i=1,\ldots,I \qquad (3\text{-}11)$$

$E_j$ is factor of production inventory in economy and $W_{ij}$ is ith individual share from jth factor ownership.

$$\sum_{i=1}^{I} W_{ij} = 1 \quad , \quad j = 1,\ldots,J \tag{12}$$

Therefore, $W_j$ shows payment to factor j.

$\Omega$ Will be the coefficient matrix $W_{ij}$ which explains the ownership structure. A composite index of income distribution such as Gini coefficient is a function of individuals' income:

$$gini \equiv g_{(y)} = g_{(T, E^*, E, \Omega)} \tag{13}$$

Equation (13) is the basis for empirical investigation of this study. This equation shows that personal income distribution is a function of variables that determines income distribution of factors and depends on the ownership structure as well[2].

$\Omega$ Matrix is determined according to historical circumstances and may vary considerably from one country to another. Despite $\Omega$ is different over time and in different countries, we can a general observation. Some factors of production such as land or investment may be concentrated in the hands of a few, because there is no limit to the accumulation of them. Other factors such as skills derived from knowledge, to some extent, cannot concentrate because there is a natural limit on the level of individual's education. If j is human capital, this observation determines a limit for $W_{ij}E_j$ variance. Consequently, if an economy mostly has land and capital in its factors inventory, there is no limit to the concentration of wealth. If an economy mostly has education (human capital), under the conditions that other factors are stable in economies, is expected to have more equal income distribution.

## *Particle Swarm Optimization Algorithm (PSO)*

Particle Optimization Algorithm (PSO) was first described by Eberhart and Kennedy in 1995. This algorithm on one hand relates to artificial life specially group theories and on the other hand to evolutionary processing algorithms and specifically evolutionary strategy which inspired by collective behavior of fish or birds to find food. A group of birds or fish are looking for food in a random environment and there is only a piece of food and none of the birds is aware of the location of food and only know its distance to the food. One of the best strategies is to follow the bird which is closer to food.

Particle Swarm Optimization Algorithm is one of the most important algorithms introduced in the field of artificial intelligence. In many cases, this method like evolutionary computing techniques operates similar to Genetic Algorithms. Similarity of PSO with GA is that both start with a basic random matrix. In this method, system starts to work with a population of initial responses and by moving these responses in successive iterations, tries to find optimal answers. In this algorithm, each particle represents an answer to a question that randomly is on the move in the context of a problem. Location shift of each particle in the search area is under its own and neighbor's influence. Therefore, the position of other particles affects on the motion and particle

[2] . It should be noted that the calculation of the Gini coefficient requires information on the full ownership structure (Ω). Other composite indicators such as factors distribution variance-covariance matrix aren't enough theoretically to calculate the Gini coefficient.

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search. The algorithm is based on the principle that each particle set its location in the search area due to the best place ever been in and the best place which exists in his entire neighborhood. The initial position of each particle in the search area is determined randomly with a uniform distribution within the definition of the problem.

Each particle is defined multidimensionality (depending on the nature of the problem) with two value $X_{\mathrm{i}}^{\mathrm{d}}$(t) and $V_i^d$(t) which represent the location and speed of dth and i*th* dimesions respectively. If $X_{\mathrm{i}}^{\mathrm{d}}$(t)is the position of dth dimension of particle *i* at time *t*, the next position of particle will be obtained from position summation of d*th* dimension of particle *i* at time *t* with particle speed *i*. particles are guided through the velocity vector. In the velocity vector also, both the result of social experience of neighboring particles and personal experience of each particle are involved. Each particle upgrades its velocity by linear combination of individual component that reflects use of knowledge and personal experience and social component indicating the neighbor′s experience. In individual component, the best position of particle pbest so far achieved and is social component, the best position which entire particle gbest have achieved will be considered. To achieve the best answer, each particle tries to change its position using below information and links.

The current position $\mathrm{X_{ij}(t)}$, current velocity $\mathrm{V_{ij}(t)}$, the distance between current position and pbest, the distance between current position and gbest, in this way the velocity of each particle changes according to the following equation:

$$V_{ij}(t+1) = \mathrm{w}\, V_{\mathrm{ij}}(\mathrm{t}) + c_1 r_1(\, pbest_{ij}(\mathrm{t}) - X_{ij}(t)) + c_2 r_2(\, gbest_j(\mathrm{t}) - X_{ij}(t)) \quad (14)$$

Where $V_{\mathrm{ij}}(\mathrm{t})$ is j*th* dimension of each particle in t*th* repetition, $c_1 c_2$ are positive constants which are used for weighting insider and collective components and are called acceleration coefficients. $r_1$,$r_2$are random numbers with distribution between zero and one ( $r_{1i}$(t) , $r_{2i}$(t) ≃ u(0,1) ) which preserve random property of algorithm. W is the inertia weight parameter.

New position of each particle is obtained from entire last position and new velocity and determined according to the following equation (Jalaee et al, 2013):

$$X_{ij}(t+1) = X_{ij}(t) + V_{ij}(t+1) \quad (15)$$

*Genetic Algorithm (GA)*

In fact, Genetic Algorithm is the most well-known type of evolutionary algorithms which was developed by John Holland and his colleagues during 1960s and 1980s. The idea of evolutionary computing was introduced in a book called “evolution strategies” by Rechenberg in 1960s. Research on Genetic Algorithm began just after studies on artificial neural networks which in both branches of biological systems are inspired as motivational and computational model. This algorithm has an iterative process and in each iteration works with one or more solutions. Genetic Algorithm begins search with a population of initial random solutions. If the final criteria aren’t satisfied, three different operators of proliferation, mutation and integration are used in order to the population be updated.

Each iteration of these three operators is known as a generation. Since displaying solutions in Genetic Algorithm is very similar to normal chromosomes and operators of Genetic Algorithm acts like genetic operators, the above process is called a Genetic Algorithm. In fact, the Genetic Algorithm searches solution area by repeating three simple steps. The first step evaluates a group of search points called a population based on the objective function. In the second step, based on the evaluated situation, some points are selected as candidates for problem solving. In the third step, genetic operators are applied on these candidates to form the next generation. This process continues until the final criteria are achieved. Final criterion is when an acceptable outcome is achieved or the maximum number of generations is repeated.

*The benefits of Genetic Algorithm and PSO Algorithm in comparison with Econometric Methods*

In traditional way and econometrics, estimation is linear and may not work well in choosing desirable answer, while Genetic method and Particle Swarm Optimization are useful for nonlinear functions and can choose the best point when faced with multiple desirable answers.

High velocity of implementing Genetic Algorithm and Particle Swarm Optimization Algorithm, requiring less data and more accuracy than econometric methods are other benefits of these algorithms which separate this approach from econometric models (Negarchi et al, 2011).

## Model Estimation

Since the main purpose of this paper is to apply nonlinear methods in interpretation of income distribution in Iran, it can be stated that according to the specified model in third part, literature review and taking into account the specific situation of Iran's economy, income distribution model is as (16) equation:

$$GINI = A_0 \,.\, (GOV)^{\alpha 1} (CPI)^{\alpha 2} (HDI)^{\alpha 3} (M_2)^{\alpha 4} \qquad (16)$$

In this study, the annual time series data of years 1979 to 2013 was used. Variables used in this study have been extracted from "Indicators of the Central Bank of the Islamic Republic of Iran" and are as follows:

1. Constant value ($A_0$)
2. Government expenditures (GOV)
3. Inflation rate (CPI)
4. Human Development Index (HDI)
5. Liquidity Volume ($M_2$)

To estimate the model with Particle Swarm Optimization Algorithm and Genetic Algorithm, MATLAB software has been used to program these two algorithms. Estimated model with Particle Swarm Optimization Algorithm (PSO) is as follows:

$$GINI = 1.0639\, (GOV)^{-0.5220}\, (CPI)^{-0.4712}\, (HDI)^{0.4128}\, (M_2)^{0.5401} \qquad (17)$$

Estimated model with Genetic Algorithm (GA) method is as follows:

$$GINI = 0.9681\ (GOV)^{-0.0788}\ (CPI)^{-0.0575}\ (HDI)^{0.0980}\ (M_2)^{0.0269} \quad (18)$$

Both estimated models show that government expenditures variables and inflation rate have indirect and negative impact on income distribution inequality, also human development index variables and liquidity has direct and significant impact on income distribution inequality, so increase in liquidity which is indicative of monetary policy leads to increased inequality of income distribution.

To evaluate the performance of the two estimated models through the algorithms, three criteria of mean standard deviation (MSE), mean absolute error (MAE) and mean absolute percentage error (MAPE). There measures are calculated as follows:

Table 1- Evaluation and Model Selection Criteria

| | |
|---|---|
| Mean Square Error | $MSE = \frac{\sum_{i=1}^{n}(y-\hat{y})^2}{n}$ |
| Mean Absolute Error | $MAE = \frac{\sum_{i=1}^{n}\lvert y-\hat{y}\rvert}{n}$ |
| Mean Absolute Percentage Error | $MAPE = \frac{\sum_{i=1}^{n}\left\lvert\frac{y-\hat{y}}{y}\right\rvert}{n}$ |

In the above equations, *n* represents the number of observations.

By analyzing and comparing the results obtained from the estimation of above models through Particle Swarm Optimization Algorithm and Genetic Algorithm, the following results were obtained:

Table 2- Comparison of estimated models with Particle Swarm Optimization Algorithm and Genetic Algorithm

| Algorithm | Particle Swarm Optimization Algorithm | | | Genetic Algorithm | | |
|---|---|---|---|---|---|---|
| Criterion | MSE | MAE | MAPE | MSE | MAE | MAPE |
| Results | 0.0001 | 0.0065 | 0.0007 | 0.0007 | 0.0154 | 0.0385 |

According to table 2, the results show that estimation error in Particle Swarm Optimization Algorithm is always less than Genetic Algorithm (GA). So, to study the impact of monetary policy on income distribution in Iran, Particle Swarm Optimization Algorithm was used.

## Conclusion

This study examines the impact of monetary policy on income distribution in Iran during the years 1979 to 2013. Therefore, in this study liquidity volume has been used as monetary policy index. Also, in this study, Gini Coefficient indicates the inequality of income distribution in Iran. So, the optimized model has been estimated using Particle Swarm Optimization Algorithm (PSO) and Genetic Algorithm (GA). According to evaluation criteria, the estimated model is selected to study the impact of economic policies on income distribution using Particle Swarm Optimization Algorithm. Research findings indicate that there is a direct and positive correlation between liquidity volume and income distribution, so the increase in liquidity volume leads to deterioration of income distribution inequality. The results show that by increasing human development index, income distribution inequality will increase in society and rising inflation rate, decreases income distribution inequality. Thus, according to the results obtained in this study, it is suggested that the government and Central Bank pay a particular attention to expansionary monetary policy and control liquidity volume.

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