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# Study on the Methods of Improving the Efficiency of Tax Reduction in Economic Downturns, Especially after COVID-19 Pandemic

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## Abstract

After experiencing the epidemic, various countries are striving to adopt various strategies to restore their economy, among which reducing taxes is one of the strategies adopted by many governments. However, the reducing taxes might cause some negative effects which will be analyzed in this paper. Moreover, this paper introduces the methods of improving the efficiency of tax reduction in economic downturns based on the evolutionary game theory, especially after COVID-19 pandemic.

## Keywords

Improving the Efficiency of Tax Reduction, Economic after COVID-19 Pandemic, Evolutionary Game Theory

## 1. Introduction

During the COVID-19 pandemic, the global economy has been analyzed to have to face multiple problems, with some of which being expected to last in the long run, including high unemployment rates and high inflations. While many of the government policies that could be used to solve those problems seems to be contradicting with each other, making the situation rather hard to change to a better status, this paper is to analyze some possible ways of resolving them.

The first economic problem incurred by many countries is the rise in cost of living while individual average income remains same or lower compared to before. In this case, the social equity was worsened and people with low income are forced to a tougher situation, leading to some of them live a vagrant life or working in grey areas and, even worse, illegally.

A policy that could be used to solve this problem is suggested as cutting direct taxes in this paper, though most scholars study the value-added tax rates cut, for example, Asanaliyevna (2020) has discussed how the tax reforms affect the budget and business atmosphere in Uzbekistan. Moreover, Funke & Terasa (2020) and Nthabiseng et al. (2022) study the value-added tax rates cut during the COVID-19 pandemic. This paper mainly studies the direct tax cutting by which it means that individual's disposable income could increase, so are the firms' profits. Hence, goods and services could be more affordable to more people, and higher retained profits for firms may also encourage them to supply more, which might bring the general price revel down, especially if the aggregate demand rise by less compared with the aggregate supply.

However, it also has the probability of leading to an inflation or causing irrational investments, which in the long run is rather harmful to the economy. The inflation can be caused due to people's willingness to store much more than the actual needs, due to their uncertainty about the future.

Therefore, the general price level might rise as the aggregate demand rises more than the aggregate supply, and with the price of consumable necessities like food and water rising the most. In this case, it might be even worse for the poor, who needs them the most to sustain their living. Another negative side-effect, namely the irrational investments, may also occur since firms and investors are more eager to make profits as soon as possible due to the pandemic. In this case, they may consider less output what might happen in the future but rather focusing more on the current. This might not be very problematic to some extent. However, as time goes along, it may turn out that many of the scarce resources have been allocated to non-sustainable fields or areas, while making profits as much as possible in the short run may lead to a greater risk of problem in the long run. In order to maximize the overall benefits of the whole economy, game theory model could be used to provide efficient solutions as shown below.

## 2. Evolutionary Game Theory

In this part, the paper presents the related basic concepts, the development and the characteristics of evolutionary game theory in order to provide a foundation for the proposal of subsequent analysis model which is introduced in part three.

### 2.1. Related Basic Concepts

Evolutionary game theory is a theory that combines the ideas of biological evolution theory and game theory, and applies dynamic evolution processes in the analysis process.

Unlike traditional game theory, the game players in evolutionary game theory are no longer completely rational assumptions, which determines that the analysis and research of evolutionary game theory are more realistic and have practical significance. The players are assumed to adopt a predetermined behavior in a programmatic manner, whose understanding of economic patterns or successful behavioral rules and strategies are revised and improved in the process of evolution, and successful strategies are imitated, resulting in some general "rules" as the behavioral standards of the players. Under these general rules, the players obtain "satisfactory" payoffs.

Evolutionary game theory first had important applications in biology, and later through research and development, it has been widely applied in sociology, economics, and other fields.

## 2.2. Development of Evolutionary Game Theory

Friedman (1991) believed that evolutionary games have great application prospects in the economic field and explored some specific dynamic systems with application prospects; studied the relationship between civic norms and evolution, believing that the long-term survival of norms depends on the evolutionary process and natural selection; Friedman and Fung (1996) analyzed the evolution of corporate organizational models in Japan and the United States using evolutionary game theory, with and without trade as the background; used evolutionary game theory to study the existence and evolutionary stability of altruistic behavior in human economic activities. Dufwenberg and Güth (1999) compared two methods of explaining economic systems in the context of duopoly competition: indirect evolution method and strategic agency method, and studied in what market environment these two methods would lead to similar market outcomes; Guttman (2001) used evolutionary game theory to study whether reciprocity can survive in groups with opportunism; Masahiko (2000) proposed a subjective game model for evolutionary games from a cognitive perspective; Haruvy and Dale (2001) used evolutionary game theory to study the optimal price and quality of free software under conditions of network externalities; Kosfeld (2002) established an evolutionary game model of abnormal shopping time in German supermarkets; used evolutionary game theory to study the formation of social norms regarding smoking behavior that takes into account the feelings of others; Jasmina and John (2004) studied the question of who performs better when imitating human behavior in public goods games with three different learning rules; Daniel, Arce and Todd (2005) studied four different types of prisoner's dilemma games and pointed out that these four prisoner's dilemmas require evolution and information requirements to achieve cooperation; Hwang, Suresh, & Bowles (2024) extend the standard asymmetric stochastic evolutionary game model to allow subpopulation sizes to differ and idiosyncratic rejection of a status quo convention to be intentional to some degree.

## 2.3. Characteristics of Evolutionary Game Theory

Evolutionary game theory is a theory that combines the ideas of biological evolution theory and game theory, and applies dynamic evolution processes in the analysis process. Evolutionary game theory has the following characteristics:

- Its research object is a group that changes over time, and the purpose of theoretical exploration is to understand the dynamic process of group evolution and explain why the group will reach this state and how to achieve it.
- The factors that affect group changes have both a certain degree of randomness and disturbance phenomena (mutations), as well as regularity presented through selection mechanisms in the evolutionary process.
- The predictive or explanatory power of most evolutionary game theories lies in the selection process of a group, which usually has a certain inertia, which also harbors the power of mutation, constantly producing new varieties or features.

The establishment of general evolutionary game models is mainly based on two aspects: selection and mutation. Choice refers to the strategy of obtaining higher payments that will be adopted by more participants in the future; Mutation refers to some individuals randomly selecting strategies that are different from the population (which may be strategies that result in higher or lower payments).

The evolution of a population is similar to the state of genes during biological evolution, with only a small probability of mutation occurring. Over time, most populations will not mutate, and only a small portion of the population will mutate. The occurrence of mutations is completely random. There are two types of mutation outcomes: getting better or getting worse, that is, the strategy chosen by the mutation population may be to make it gain higher returns, or vice versa, to get less returns. According to the idea of evolutionary game stability strategy, a random game is played between a small group with mutations and a large group without mutations. If the payment received by the small group with mutations in the game is less than the payment received by the individuals in the non-mutation group, the small group with mutations cannot invade the large group without mutations. As time progresses, it gradually eliminates and disappears. If the situation is opposite, the mutated small group successfully invades the original group.

In a group, a group that chooses an evolutionarily stable strategy must be able to resist any small number of mutated groups invading the group. At this point, it is said that the strategy chosen by the group is an evolutionary stability strategy.

## 3. Analysis on Tax Reduction in Economic Downturns Based on Evolutionary Game Theory

This article constructs a double-layer interactive evolutionary game model to better analyze and simulate the dynamic evolution process of government tax reduction and changes in real GDP per capita. This model can also be seen as a party game, which includes government tax reduction, changes in enterprise product prices, and changes in gross domestic product, overcoming the limitations of classical game theory that can only analyze two aspects. The prerequisite for using classical game theory for analysis is to assume that all participants are rational, but due to limitations in information and other aspects, this rational assumption is not in line with the actual situation. Evolutionary game theory is based on the study of participants with bounded rationality, which can make the model more realistic.

Under the assumption that in a game strategy both parties have bounded rationality with both the maximization of their own profits and the improvement of benefits considered in their choice, this paper constructs the model as presented from Equation (1) to Equation (19).

### 3.1. Construct the Utility Function

Firstly, this paper constructs the utility function as follows:

$$U_{x1} = U\left(x_{11}, x_{12}, x_{13}\right) \tag{1}$$

where,

$U_{x1}$ denotes the utility of the governments.

$x_1$ denotes the strategy set {Do not reduce tax, Reduce tax}.

$x_{11}$ denotes the effect on national fiscal revenue.

$x_{12}$ denotes the effect on enterprise production price adjustment.

$x_{13}$ denotes the effect on real GDP per capita.

$$U_{x2} = U\left(x_{21}, x_{22}\right) \tag{2}$$

where,

$U_{x2}$ denotes the utility of the enterprises.

$x_2$ denotes the strategy set {Increase product price, Reduce product price}

$x_{21}$ denotes the effect on enterprises' income.

$x_{22}$ denotes the effect on real GDP per capita.

$$U_{x3} = U\left(x_{31}, x_{32}\right) \tag{3}$$

where,

$U_{x3}$ denotes the utility of individuals.

$x_3$ denotes the strategy set {Improves (Increase by about k%) real GDP per capita, Reduce real GDP per capita}

$x_{31}$ denotes the effect on individuals' income.

$x_{32}$ denotes the effect on real GDP per capita.

$$U = U_{x1} + U_{x2} + U_{x3} \tag{4}$$

where,

$U$ denotes the whole utility.

Note the value should be dimensionless processed. That is:

Let m be any numerical value in the set and $m_{\max}$ be the maximum value and $m_{\min}$ be the minimum value, then

$$m' = \left(m - m_{\min}\right) / \left(m_{\max} - m_{\min}\right) \tag{5}$$

### 3.2. Construct the Benefit Matrix

Then, this paper constructs a double-layer interactive evolutionary game model as following Table 1 & Table 2:

**Table 1.** The payoff matrix between the government and enterprises.

| | | Enterprises | |
|---|---|---|---|
| | | Increase product price | Reduce product price |
| Government | Do not reduce tax | $(a_{11}, b_{11})$ | $(a_{12}, b_{12})$ |
| | Reduce tax | $(a_{21}, b_{21})$ | $(a_{22}, b_{22})$ |

**Table 2.** The payoff matrix between Real GDP per capita and enterprises.

| | | Enterprises | |
|---|---|---|---|
| | | Increase product price | Reduce product price |
| Real GDP Per Capita | Improves (Increase by about k%) | $(a_{11}, b_{11})$ | $(a_{12}, b_{12})$ |
| | Does not improve | $(a_{21}, b_{21})$ | $(a_{22}, b_{22})$ |

where

$a_{ij}$ denotes the pay off for the government under the conditions of *i* and *j* and the value should be dimensionless processed like Equation (5);

$b_{ij}$ denotes the payoff for the enterprises under the conditions of *i* and *j* and the value should be dimensionless processed like Equation (5).

From table, the profit function of government $f_{1(x1,x2)}$ is described as following:

$$f_{1(x1,x2)} = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \tag{6}$$

The profit function of enterprises $f_{2(x1,x2)}$ is described as following:

$$f_{2(x1,x2)} = \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix} \tag{7}$$

where,

$c_{ij}$ denotes the pay off for real GDP per capita under the conditions of *i* and *j* and the value should be dimensionless processed like Equation (5);

$b_{ij}$ denotes the pay off for the enterprises under the conditions of *i* and the value should be dimensionless processed like Equation (5);

Real GDP Per Capita = [C + I + G + (X − M)]/number of people and adjusted for inflation;

k% represents a favorable percentage increase in real GDP per capita decided by the government.

We can see that if consumption (which is influenced by individuals) increases as well as investments (which is influenced by enterprises) and government spending after economic downturns, real GDP per capita is likely to improve.

The payoff function of individuals $f_{3(x1,x2)}$ is described as following:

$$f_{3(x1,x2)} = \begin{pmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{pmatrix} \tag{8}$$

The process of determining specific tax reduction plans by the government is a gradual exploration. On the one hand, it is necessary to summarize the experience and lessons learned from implementing relevant policies in similar environments in history in various countries. At the same time, it is also necessary to choose to implement pilot policies within a certain range, and make the next decision based on the effectiveness of pilot enterprises. Therefore, when considering specific tax reduction plans, the government should also fully consider the specific situation of enterprises, choose the optimal strategy, and implement specific tax policies.

Firstly, we assume that both the government and the enterprises will choose the strategy that maximizes their payoffs, so

$$P_{x1} = \max f_1\left(x_1, x_2\right) \tag{9}$$

where,

$P_{x1}$ denotes the payoffs of government strategy selection.

$$P_{x2} = \max f_2\left(x_1, x_2\right) \tag{10}$$

where,

$P_{x2}$ denotes the payoffs of enterprises strategy selection.

According to the tax policy, enterprises will also adjust the strategies then

$$P_{x2} = \left(x_2 : f_2\left(x'_1, x_2\right)\right) = \max f_2\left(x'_1, x_2\left(x_1\right)\right) \tag{11}$$

where,

$x_2\left(x_1\right)$ denotes the optimal strategy adopted by enterprises under known government tax reduction policies.

Similarly, the government will adjust tax policies appropriately based on feedback from enterprises, then

$$P_{x1} = \left(x_1 : f_1\left(x_1\left(x_2\right), x_2\left(x_1\right)'\right)\right) = \max f_1\left(x_1\left(x_2\right), x_2\left(x_1\right)'\right) \tag{12}$$

Correspondingly, enterprises will adjust the strategies then

$$P_{x2} = \left(x'_2 : f_2\left(x_1\left(x_2\right)', x_2\left(x_1\right)\right)\right) = \max f_2\left(x_1\left(x_2\right)', x_2\left(x_1\right)\right) \tag{13}$$

At the same time, enterprises choose the strategies also related to the real GDP per capita, so

$$P_{x2} = \left(x'_2 : f_2\left(x_2\left(x_1, x_3\right), x'_3\right)\right) = \max f_2\left(x_2\left(x_1, x_3\right), x'_3\right) \tag{14}$$

Hence, the enterprises' strategies will affect the government strategies.

$$P_{x1} = \left(x'_1 : f_1\left(x_1\left(x_2\right), x_2\left(x_1\right)'\right)\right) = \max f_1\left(x_1\left(x_2, x_3\right), x_2\left(x_1, x_3\right)'\right) \tag{15}$$

Then $P_{x2}$ will change as following:

$$P_{x2} = \left(x'_2 : f_2\left(x_1\left(x_2\right)', x_2\left(x_1\right)\right)\right) = \max f_2\left(x_1\left(x_2, x_3\right)', x_2\left(x_1, x_3\right)\right) \tag{16}$$

After multiple iterations, we assume there exists a tax reduction strategy*, which meets the conditions as following:

$$f_1\left(x_1, \left(x_2, x_3\right)*, x_2\left(x_1, x_3\right)*\right) > f_1\left(x_1, \left(x_2, x_3\right), x_2\left(x_1, x_3\right)*\right) \tag{17}$$

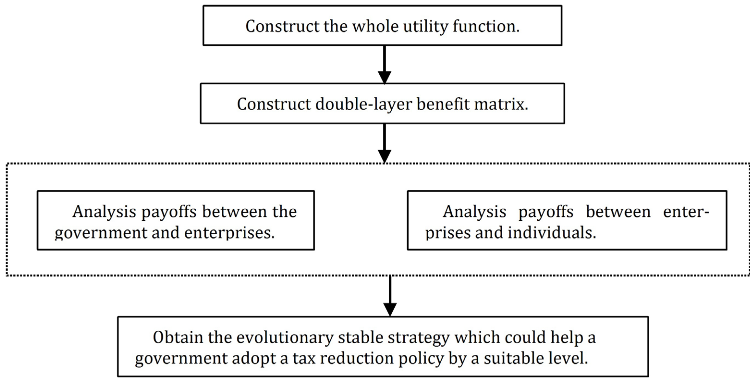


**Figure 1.** Logical reasoning flowchart of the analysis model.

$$f_2\left(x_1,\left(x_2,x_3\right)*,x_2\left(x_1,x_3\right)*\right) > f_2\left(x_1,\left(x_2,x_3\right)*,x_2\left(x_1,x_3\right)\right) \tag{18}$$

$$U^* \geq U_0 \tag{19}$$

where,

$U_0$ denotes the current total utility function.

Therefore, this strategy $U^*$ is an evolutionary stable strategy. If this strategy is the strategy chosen by all game players, then we can say that the system has reached an evolutionary stable equilibrium at this point.

This paper proposes a logical reasoning flowchart (shown as **Figure 1**) to explain the rationality of the model in order to better understanding.

## 4. Conclusion

Reducing taxation is an important fiscal policy, which can increase the post tax income of companies and individuals, stimulating businesses to expand investment and individuals to increase consumption, thereby increasing demand and helping to overcome economic recession. It may also increase the post tax income of companies and individuals, helping promote economic growth and social stability.

Therefore, a reduction in (direct) tax during economic is of great importance. While during economic downturns like the time period during and after COVID-19 pandemic, it is very important to ensure the policy of tax reduction being carried out efficiently. As analyzed in this paper, we can thus suggest that the obtained $U^*$ could help a government adopt a tax reduction policy by a suitable level. However, at present it is difficult to collect enough statistical data of different countries to validate this theoretical model, so this paper proposes a logical reasoning flowchart **Figure 1** to help explain the rationality of the analysis process which is presented from Equation (1) to Equation (19), while in the future, the aim is to further focus on collecting more relevant statistical data to verify the effectiveness and practical applicability of this model.

## Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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