Statistical measure analysis of new population opportunities under the background of negative growth

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Abstract: *In 2022, China experienced its first population decline since 1961, with a decrease of 850,000 individuals. Data from the Bureau of Statistics revealed a birth rate of 9.56 million and a death rate of 10.41 million, resulting in a negative natural population growth rate of -0.60‰. This shift presents both opportunities and risks. Our paper explores these opportunities by focusing on the population and analyzing it using seven evaluation indicators. We categorized indicators based on input-output characteristics, established a population dividend evaluation system with seven sub-systems, and processed reliable data from government sources, normalizing it, addressing negative impact indicators, and conducting principal component analysis. The resulting indicators are: demographic dividend, longevity opportunity, human capital, allocation efficiency, economic development, financial expenditure, and labor system. Drawing from our analysis, we developed the DEA-CCR model and used the DEA-solver to analyze it. Our findings indicate that, in the past decade, three years marked DEA efficiency in our country, reflecting optimal input-output ratios and maximized human capital utilization. However, for years of inefficiency, we propose promoting coordinated development, adjusting labor and financial inputs, and addressing societal issues. We recommend optimizing resource allocation, investing in education, transforming from a populous to a talent-driven nation, and strengthening public infrastructure. By implementing these strategies, we aim to address negative population growth challenges and seize new demographic opportunities.*

Keywords: *Population negative growth, DEA-CCR model, population dividend, population evaluation index system*

1. Introduction

According to the population transition theory, the negative population growth in the post-population transition period is a special type of population reproduction under the effect of ultra-low fertility rate, a phenomenon in which the death population exceeds the birth population, and the total population and growth rate, age structure and distribution structure change rapidly under the condition of no migration population.[1]

Negative population growth is a population phenomenon rarely experienced in human history, which will bring a series of opportunities and challenges to economic and social development, and it is necessary to objectively understand and actively seek new population opportunities brought by negative growth[2]. The negative population growth in our country is gradual and mild in the short term, accelerated and drastic in the long term, and intertwined with the aging of young children and population flow. The huge population size is the resilience of China's economic stable development into the high-income stage, and negative population growth will help ease the pressure of population size and promote the balance between supply and demand of public services. In the future, we need to dialectically view the opportunities and challenges contained in negative population growth, strengthen research on development strategies for negative population growth, strive to smooth negative population growth, actively cope with the aging of young children, effectively improve the quality of the population, and make full use of domestic and international human resources.

China is likely to become a country with the fastest negative population growth and population aging in the world. We need to recognize the seriousness of the rapid negative population growth in the future as we did decades ago, and we need to carry out institutional innovation at multiple levels such as population, economy and society to adapt to and cope with this changing trend and promote the coordinated development of population and economy and society[3][4].

2. Materials and methods

This paper takes the demographic dividend opportunity under the background of negative population growth in China as the analysis object, and the relevant data are all from the National Bureau of Statistics, which makes the data authoritative and the conclusion more credible. This paper selects representative first-level input and output indicators from the four aspects of economy, society, resources and population, and then selects more detailed second-level indicators to achieve the purpose of improving data screening and building an evaluation index system. The indicators extracted from the economic level are: national financial expenditure, gross domestic product, per capita GDP, added value of the primary industry, added value of the secondary industry, added value of the tertiary industry, per capita consumption expenditure of residents. The indicators selected at the resource level are: total water supply, domestic energy consumption, heating area; In terms of population, this paper extracts the following indicators: Employment rate, birth rate, number of junior high school graduates, number of ordinary high school graduates, number of adult college graduates, number of ordinary college graduates, number of Internet college graduates, number of adult college graduates, number of ordinary college graduates, number of Internet college graduates, number of college graduates, number of 0-14 years old population, 15-64 years old population, population over 65 years old The number of workers, scientific research personnel, labor force and retirees in employment; At the social level, this paper selected social insurance fund expenditure, urban basic pension fund expenditure, basic medical insurance expenditure, social health security and social welfare OFDI flow, education expenditure, and total health expenditure as indicators for further processing.

In the analysis method, the paper adopts data envelopment analysis (DEA). This method has an absolute advantage in dealing with the problem of effectiveness comprehensive evaluation of multi-input-multi-output. DEA does not need to figure out the correlation between the input and output of each DMU, and only needs to use the extreme value method to finally intend the opponent to take this variable as the overall measurement standard. DEA model is a quantitative analysis method to evaluate the relative effectiveness of comparable units of the same type according to multiple input indexes and multiple output indexes, using the method of linear programming. It is also a method to deal with multi-objective macrobook problems with multiple inputs and multiple outputs.

DEA model can comprehensively consider multiple input and output indicators, so as to comprehensively evaluate the performance of demographic dividend in different aspects. This comprehensive evaluation method helps to reveal the impact of demographic dividend on economic growth, labor supply, social welfare and other aspects, and provides a comprehensive basis for policy makers to make decisions. There are many models under this method. According to the research content of this paper, we choose the classical CCR model. The ten years from 2013 to 2019 were selected as the decision-making unit, combined with multiple comprehensive indicators determined by principal component analysis, and the DEA-CCR model was used to carry out the research.

3. Background of the study area

In the face of the rare phenomenon in human history, many scholars put forward new opinions and new ideas at the moment of major changes. Liu Houlian and Zhang Gang have the advantages of the current population situation in China: large-scale elderly human resources need to be developed, and China's human resources still have comparative advantages; Pressure on public services has eased; The population pressure will be eased, and the long-term balanced development of population will be further promoted[5][6].Ding Juan pointed out that the negative population growth in China is not only a crisis, but also an opportunity: it is the window period for the transformation of human resources into human resources; The decline in population is forcing a qualitative change in scientific and technological innovation; The ecological bearing pressure has been relieved to some extent[7].

With the deepening of the understanding of population opportunities under negative population growth, there are more and more researches on this kind at home and abroad. According to their own research direction, scholars also built a model to analyze and integrate this. We should understand scientifically and fully the positive and negative effects of the new population situation. In terms of measures, we should take the initiative to adapt and fully explore the new opportunities contained in the new population situation; In action, we must actively respond to the comprehensive challenges posed by the new population situation to development, strive to effectively transform the population opportunities in the new era into new demographic dividends, and promote high-quality economic and social development

4. Paper topic

This paper mainly takes demographic dividend, longevity opportunity window, human capital, allocator efficiency level, human capital, labor force and financial expenditure as the research basis, takes employment rate, average years of schooling and gender structure of population as the indicators to study new population opportunities, and takes the national population as the research object. The research scope is wider and can better reflect the actual situation of China's population. Look for new demographic opportunities in our country.

4.1. Demographic dividend opportunity evaluation system

Table 1: Demographic dividend opportunity evaluation system

First-level indicators	Secondary indicators	Tertiary indicators
Cost Index System X	Human capital indicator system X1	Education expenditure (ten thousand yuan) x1
		Total health expenditure (100 million yuan) x2
	Fiscal expenditure indicator system X2	State financial expenditure (billion yuan) x3
		Social security fund expenditure (100 million yuan) x4
		Expenditure of basic urban endowment insurance funds (100 million yuan) x5
		Basic expenditure for medical insurance (100 million yuan) x6
	Labor index system X3	Employed persons (10,000) x7
		Research staff (10,000 thousand years) x8
		Labor force (10,000) x9
Efficiency indicator variable Y	Demographic dividend index system Y1	Employment rate (%) y1
		Birth rate (‰) y2
		Number of junior high school graduates (10,000) y3
		Number of ordinary high school graduates (10,000) y4
		Number of adult college graduates (10,000) y5
		Number of general college graduates (10,000) y6
		Number of network college graduates (10,000) y7
		Number of adult undergraduate graduates (10,000) y8
		Number of ordinary undergraduate graduates (10,000) y9
		Number of online undergraduate graduates (10,000) y10
		Number of undergraduate graduates (10,000) y11
		The number of college graduates (10,000) y12
		Population aged 0-14 (10,000) y13
		Population aged 15-64 (10,000) y14
		Population over 65 years old (10,000) y15
		Health Social security and social welfare Outward direct investment flows (10,000 USD) y16
	Economic development Indicator system Y2	Gross Domestic Product (billion yuan) y17
		Per capita GDP (yuan) y18
		Value added of primary industry (100 million yuan) y19
		The added value of the secondary industry (100 million yuan) y20
		The value added of the tertiary industry (100 million yuan) y21
		Per capita disposable wage income (Yuan) y22
	Longevity opportunity window indicator system Y3	Per capita consumption expenditure (Yuan) y23
		The number of retirees in employment (10,000) y24
	Capital allocation efficiency index system	Total water supply (tons) y25
		Domestic energy consumption (tons of standard coal) y26
		Heating area (100 million square meters) y27
		Per capita disposable income (yuan) y28

The analysis of demographic dividend needs to consider various factors of the country, so the analysis of demographic dividend is a multi-input and multi-output evaluation problem[8],Therefore, this paper chooses DEA method which has its own outstanding advantages for this kind of problem. In this method, the index of consumption in the process of population development is taken as the input index, and the index of benefit in the process of population development is called the output index. The first step divides the 37 indicators into two categories: input indicators and output indicators. At this time, because the nature of each category of indicators is relatively chaotic, the second step is to divide the two categories of indicators again according to their levels. The results of input index are divided into three subsystems, namely, human capital index system, financial expenditure system and labor index system. The output index is divided into four subsystems, which are: demographic dividend index system, economic development index system, longevity opportunity window index system and capital allocation efficiency index system[9].

The specific demographic dividend opportunity evaluation index system is shown in Table 1:

4.2. Data optimization processing

All index data are from the National Bureau of Statistics and are obtained in the past ten years. As the sample size is small, ignoring missing values will affect the accuracy of the result, and all the vacant data is filled by the average value, and the index uses the Normalization method of Min-Max to normalize data. In addition to the normalization of the sample, this paper also deals with the negative influence index.

We can divide the data into two categories: one is that it has a positive effect on the comprehensive evaluation index, such as gross GDP and per capita GDP in the subsystem of economic development indicators; The other one has a negative impact on the comprehensive evaluation index, such as social security outbound investment, the more social security outbound investment, the lower the comprehensive evaluation index of the demographic dividend subsystem should be, and the greater the negative impact will be. In addition, there is the expenditure on education in the human capital index subsystem, the lower the proportion of expenditure on education. The index subsystem of social and economic development should be higher. It can be seen that expenditure for education has a negative impact on social and economic development. Since the principal component analysis method uses linear weighting for comprehensive evaluation, it is obviously wrong to add the negative impact index and the positive impact index with linear weight. Therefore, we conducted sign-changing processing on all the data of ten indicators such as social security outbound investment and expenditure for education to meet the requirements.

4.3. Principal component analysis

Based on the evaluation system established above, principal component analysis is carried out on the seven sub-systems successively. The sub-system "demographic dividend" contains more indicators. The research finds that the contribution rates of the first principal component, the second principal component and the third principal component are 66.99%, 18.83% and 7.57%, respectively, and the final expression is that the cumulative contribution rates of the first three principal components total 93.38%. More than 90% of the requirements were met, so the first three principal components were extracted.

By combining the first three principal components of Y1, the comprehensive evaluation index Y1* of Y1 can be obtained

Combining the first three principal components of Y1 gives the comprehensive evaluation index of

$$Y_1^* = (F_1)_{Y_1} + (F_2)_{Y_2} + (F_3)_{Y_3}$$

The remaining subsystems are processed in the same way, and the final data can be substituted into the expression to get the comprehensive evaluation index result after the principal component processing

As can be seen from the table 2, the overall growth trend of the cost composite index, but in the past two years there has been a downward trend, indicating that under the background of negative growth, the new population opportunities are increasing, and the cost of our input is decreasing. In the benefit index, the longevity opportunity window has shown a downward trend in recent ten years, and the demographic dividend has fluctuated in recent ten years, but in recent years, it has shown an overall upward trend. The efficiency of capital allocation is increasing due to the negative population growth in recent years, and the economic development has shown an upward trend in the past ten years.

Table 2: Results of comprehensive evaluation index

Indicators	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013
Fiscal expenditure	0.61	2.71	2.05	1.79	0.96	0.05	1.03	1.73	2.41	2.91
Economic development	3.89	3.12	1.65	1.14	0.3	0.62	1.5	2.12	2.63	3.22
Labor	0.93	5.8	4.82	1.92	1.08	0.11	1.84	2.48	3.09	3.6
Demographic dividend	0.29	0.81	0.49	1.76	1.18	0.93	1.34	1.09	0.23	1.26
Human capital	0	1.09	2.03	1.45	0.74	0.09	0.56	1.08	1.67	2.08
Longevity Opportunity window	2.9	2.46	1.39	1.15	0.38	0.34	0.98	1.67	2.31	2.97
Efficiency of capital allocation	44068.21	43270.28	46119.15	44158.99	42338.76	39839.05	37321.65	34594.51	32190.64	30497.31

4.4. Establishment and solution of Data Envelopment analysis (DEA-CCR) model

In this section, the C2R model in DEA is selected to analyze the problem of urban sustainable development, and the decade from 2013 to 2019 is selected as the decision-making unit, combined with multiple comprehensive indicators determined by principal component analysis, and the DEA-CCR model is used to carry out research. Where: the input variables are: capital input comprehensive index, labor force comprehensive index, resource consumption comprehensive index; The output variables are: economic development comprehensive index, population development comprehensive index, social development comprehensive index.

In order to meet the requirements of DEA-CCR model, the input and output indexes are greater than 0, the six categories of comprehensive indexes are normalized.

After the data normalization, the DEA-CCR model is used to solve the problem. The solution results are as follows:

For input index:

Table 3: Input results for input indicators

Year	Theta.	K	Relative effectiveness of DEA
2013	1	1	DEA effective
2014	0.946	< 1	Ineffective
2015	0.96	< 1	Ineffective
2016	1	1	effective
2017	0.847	< 1	Ineffective
2018	0.804	< 1	Ineffective
2019	0.768	< 1	Ineffective
2020	0.817	< 1	Ineffective
2021	0.618	< 1	Ineffective
2022	1	1	effective

According to Table 3, between 2013 and 2022, China's input in fiscal expenditure, labor expenditure and human capital in 2022, 2016 and 2013 has reached the effective level. Most of the other years have basically reached the effective level, but the ratio of input to output in 2021 is relatively low, only about 0.6

For output indicators, the following table:

Table 4: Output indicators

Year	θ	K	Relative efficiency of DEA
2013	1	1	effective
2014	0.946	>1	Ineffective
2015	0.96	>1	Ineffective
2016	1	1	effective
2017	0.847	>1	Ineffective
2018	0.804	>1	Ineffective
2019	0.768	>1	Ineffective
2020	0.817	>1	Ineffective
2021	0.618	>1	Ineffective
2022	1	1	effective

According to Table 4, between 2013 and 2022, China achieved effective output in longevity opportunity window, capital allocation efficiency, economic development and demographic dividend in 2022, 2016 and 2013. Most of the other years have basically reached the effective rate, but the output efficiency in 2021 is low, only reaching about 0.6.

As can be seen from the table, there is basically no need for improvement except that the projected value of 2013, 2022 and 2016 is 1; In 2014, 2015, 2017, 2018, 2019, 2020 and 2021, we will also need to reduce investment in fiscal expenditure, labor expenditure and human capital expenditure. To make sure the scale is right.

It can be seen from the table that the projected value of 2022, 2016 and 2013 is 1, and the scale of output is appropriate. The projected value for 2020, 2019, 2018, 2017, 2015 and 2014 is greater than one, in which the longevity opportunity window, capital allocation efficiency, economic development and demographic dividend need to be scaled down.

5. Conclusions

This paper mainly uses the data envelopment analysis method to evaluate the social, economic, resource allocation and demographic dividend influences caused by population changes in China in the past ten years, reflecting the impact of population changes in the country in the decade from 2013 to 2022. By comparing the DEA analysis results of different input-output index combinations. The factors that have significant influence on the effectiveness of DMU are identified. We came to the following conclusions:

Based on the characteristics of multi-input and multi-output of demographic dividend in the context of negative population growth, combined with China's own characteristics and following the scientific and reasonable principles, this paper sets up an evaluation index system of demographic dividend in the context of negative population growth based on DEA method, so as to carry out a real and objective evaluation of the influence ability of all aspects brought about by population change in the past ten years. From the perspective of the basic elements of population, China no longer has the objective conditions for rapid economic growth due to the shrinking labor force and aging population. The realization of high-quality economic development has become an inherent requirement and inevitable choice under the trend of negative population growth, which is mainly reflected in the fact that population shrinking and aging provide a "window of opportunity" for the improvement of ecological environment. The reduction of labor force and the deepening of aging force the transformation of industrial upgrading and economic development mode, and high-quality development is the best way to achieve the improvement of national welfare under the trend of negative population growth[10][11].

According to the DEA evaluation results, the DEA was effective in 2022, 2016 and 2013, indicating that the country obtained greater value with the least amount of population capital input in these three years, that is, human resources were utilized to the greatest extent. In the past ten years, there are 3 years through analysis that DEA is effective, the input-output ratio reaches the optimal, the national demographic dividend, resource allocation efficiency, economic development longevity opportunity window is currently developing relatively stable, it can be seen that the current population growth rate is still within the scope of actively promoting China's development. In 2021, 2020, 2019, 2018, 2017, 2015, and 2014, the amount of input indicator resources varied from too high to too low to too high and then to too low, resulting in low utilization of input resources. In order to maximize the effectiveness of DEA, according to Table 3, financial expenditure, labor and human capital input should be reduced. Because China is currently in the context of negative population growth, and the DEA analysis in 2022 is valid, China is currently in the stage of population resource adaptation. However, with the continuous decline of growth rate and population, it is inevitable that DEA is ineffective.

Through the comparative analysis of the input-output index combination, we can see that for the three input subsystems, the weight of fiscal expenditure is decreasing year by year, and the labor expenditure is decreasing from year by year to increase. Therefore, China should pay more attention to the labor subsystem, concentrate on the development of education and scientific research, and coordinate the development of highly educated talents to provide social employment window. Accelerate the transformation of China from a populous country to a talent power, and give preferential policies and social welfare guarantees to high-quality talents; Second is the sub-system of government expenditure, our country should strengthen the social security and optimize the social security system, so that no one is missed. For the four output subsystems, capital allocation efficiency has the greatest impact on population change. China should focus on and pay comprehensive attention to capital allocation issues, timely correct the direction, such as strengthening internal and external supervision, timely inspection and adjustment of resource allocation plans. Secondly, the impact of economic development on population change is also relatively large. Our country should persist in the development of economy and constantly move closer to an economic power. The focus of economic development will be on the real economy, promote new industrialization, and accelerate the building of a strong manufacturing and quality country.

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