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Revising life expectancy index to explain its consistency to other vital indices in Iran

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Abstract
In reports on human development, life expectancy at birth together with gross domestic product and literacy rates are taken into account for comparison and ranking of countries in terms of development. Calculation of life expectancy index independently from other vital indices is not compatible with these indices in health planning and policies. This study aim to revise life expectancy index using a statistical regression model between life expectancy in various provinces in 2006 and vital indices of natural population growth rate, crude birth and death rates, total fertility rate, and under 5 mortality rate in these provinces in 2009, which will indicate the effects of these indices on life expectancy in Iran. Revised life expectancy index at birth in 2009 shows the influence of vital indices on this index and the tangible changes in ranking of provinces compared to 2006. These changes are the result of policies to improve vital indices in provinces with improved ranking by affecting life expectancy. Life expectancy index is obtained based on life table and almost independent from vital indices. Vital indices are typically used in health policy and planning targets. In this study, effect of vital indices on life expectancy index is shown for the first time using revised life expectancy index by explanation of a statistical-regression correlation model between life expectancy and vital indices.

Keywords: Health Status Index, Human Development, Life Expectancy, Iran

Introduction
Life expectancy at birth is simply used to assess international ranking of countries in terms of development of health sector. The United Nations considers this index the most important indicator of health status in various countries, and uses this, together with socioeconomic indices of gross national income per capita and literacy to calculate a single Human Development Index (HDI) [1]. The need to simplify HDI by using only three basic indices is due to restricted access to other essential statistics in developed and developing countries [2](192 countries in total), which are put next to each other for comparison in human development reports. Moreover, calculation of HDI using these three basic indices has never ranked developed countries below the expected

position or below developing countries with improper development conditions[3]. Generally, the importance of life expectancy in national comparisons and calculation of HDI in UN reports has drawn attention of health sector experts to this index for explaining status of general health of the nation[4]. Excessive attention to this index has led to underestimating the effects of other vital indices on health sector development in domestic policies and studies. Yet, indices such as mortality and fertility rates may have greater importance in terms of application and policy-making than crude life expectancy index.

In addition to its use in calculation of human development index, one of the main reasons for using life expectancy index at birth is its apparent features, which makes it suitable for use as a unique alternative to a series of vital indices in a given geographical region or country [5]. However, this index has its own disadvantages. Basically, life expectancy index should be measured every year or every other year based on census statistics and population sampling in order to be considered valid. However, these conditions are not easily met, and these data might not be useful for finding society's health structure and its annual changes in later years. Moreover, data about the number of living people in each age group and gender, mortalities and their registration system based on statistical sampling, and assumption of equal registration cover in areas near and far from major and small cities all influence and limit the importance of life expectancy and its application in policy-making. As will be illustrated in this article, statistical-regression correlation between life expectancy and other vital indices is almost impossible to observe. In statistical-regression, correlation can be shown according to a logically defined functional relationship. To show correlation between life expectancy and other vital indices, regression coefficients should show that positive or negative changes in vital indices make life expectancy change with longer or shorter life at a significant level and high percentage of explain ability of the relationship. Essentially, without considering regression correlation between life expectancy and vital indices (which also indicates the effect of state interventions), these indices cannot be considered to have statistical correlation and cause and effect correlation (in which improved vital indices is the cause and increased longevity the effect). So far, in domestic and foreign studies, this type of correlation has not been investigated. The generally accepted assumption in all these studies is that improvement in vital indices leads to increased life expectancy. In this study, the results from statistical assessment of the correlation between these sets of indices will show that Iranian revised life expectancy at birth, and compatibility or logical relationship between this and other vital indices can provide the means to assess state interventions.

Method

In this analytical study, registered statistics of vital and life expectancy at birth indices published by the Ministry of Health (Iran) for 2006 and 2009 were used. Main variables studied included the latest results of life expectancy calculations for different provinces in 2006, and vital indices for different provinces in 2009, including natural growth rate, crude birth rate, crude death rate, total marital fertility rate, under 5 mortality rate, and maternal mortality rate due to pregnancy and labor complications. These vital indices were chosen for their importance in explaining the health status of countries by the UN Development Program (UNDP) and United Nations Third Millennium Development Goals [6].

These In this study, attempt is made to present revised life expectancy index adjusted with vital indices and the effect of state interventions using data from vital indices affecting life expectancy, and a regression model, through statistical-regression correlation and regression estimation in Eviews7 software, and revision of life expectancy at birth calculation.

This regression model is used for its two important features: to show statistical correlation and cause and effect correlation, and to explain the effect of improved vital indices on increased life expectancy. Regression correlation models have also been used in disease burden model to explain the relationship between mortality rate in different age and gender groups and causes of death and per capita income, human resources and time [7]and also to estimate DALE index[8].

Adjusted life expectancy index with effects from vital indices and state interventions is found as follows:

$$LE = \lambda_0 + \lambda_1 * MF + \lambda_2 * NG + \lambda_3 * IM + \lambda_4 * MM + \lambda_5 * CB + \lambda_6 * CD \quad (1)$$

Where:

LE= Life Expectancy at birth

MF= Total Marital Fertility rate

NG= Natural Growth rate

IM= Under 5 Mortality rate

MM= Maternal and Labor Complications

CB= Crude Birth rate

CD= Crude Death rate

In the above equation, $\lambda_6, \lambda_5, \lambda_4, \lambda_3, \lambda_2, \lambda_1$ are coefficients of relative changes in dependent variable LE due to changes in each explanatory variable on the right of equation (1). λ_0 shows potential relative changes in dependent variable irrespective of explanatory variables. These coefficients can be estimated based on explanatory variables for 30 provinces in 2006 using statistical model of regression correlation coefficients.

There are two main problems for estimating above coefficients: First, explanatory variables on the right of equation (1) cause colinearity, non-significance and high variance for these coefficients. The colinearity is already evident from the simple linear relationship NG=CB-CD. Therefore, here on CB and CD are replaced with NG. Second, since life expectancy is calculated independently from vital indices of fertility, population growth, and maternal and under 5 mortality, finding a regression correlation between life expectancy and these vital indices is difficult. In fact, in practice, whereas changes in natural growth rate (NG) should cause changes in life expectancy, LE together with other vital indices, especially MF, IM, and MM affect NG. This can be shown by a simple modification in equation (1) as follows:

$$NG = -\frac{\lambda_0}{\lambda_2} + \left(-\frac{\lambda_1}{\lambda_2}\right) * MF + \frac{1}{\lambda_2} * LE + \left(-\frac{\lambda_3}{\lambda_2}\right) * IM + \left(-\frac{\lambda_4}{\lambda_2}\right) * MM \quad (1\text{-}1)$$

Equation 1-1 may be simplified as:

$$NG = \delta_0 + \delta_1 * MF + \delta_2 * LE + \delta_3 * IM + \delta_4 * MM \quad (2)$$

Equation (2) shows the effect of vital indices (except crude birth and death rates) on natural growth rate. Coefficients $\lambda_4, \lambda_3, \lambda_2, \lambda_1, \lambda_0$ in equation (1) may be found by placing values found for $\delta_4, \delta_3, \delta_2, \delta_1, \delta_0$ in equations (3) as follows:

$$\lambda_0 = \left(-\frac{\delta_0}{\delta_2}\right),\ \lambda_1 = \left(-\frac{\delta_1}{\delta_2}\right),\ \lambda_2 = \frac{1}{\delta_2},\ \lambda_3 = \left(-\frac{\delta_3}{\delta_2}\right),\ \lambda_4 = \left(-\frac{\delta_4}{\delta_2}\right) \quad (3)$$

Coefficients $\lambda_4, \lambda_3, \lambda_2, \lambda_1, \lambda_0$ can then be used to find revised life expectancy in equation (1).

Now, to find regression coefficients $\delta_4, \delta_3, \delta_2, \delta_1, \delta_0$ in equation (2), assumptions and colinearity between explanatory variables in this equation should be statistically re-examined. Results of this equation showed that minimum acceptable significance level of 10% is not established for coefficients s due to: A- relative independence of assumptions and population statistics used in calculation of life expectancy from statistical sampling results for vital indices, B- colinearity in vital indices.

To resolve this, two-stage estimation method is used in regression equation (2), in which, first, a regression relationship is established between at least two explanatory variables on the right of equation (2), which should be both theoretically acceptable and provide the best estimate, as shown below:

$$LE = \beta_0 + \beta_1 * MF \quad (4)$$

Regression coefficients β_0 and β_1 can be found by solving equation (4), as shown in Table 1.

Durbin-Watson statistic cannot confirm a lack of correlation in the model. However, LM (1) and LM (2) tests for 1st and 2nd correlation ranks, compared to critical numerical value in Table (X2) at 5% significance level, confirm a lack of correlation up to the 2nd rank. White nR2 test, compared to critical numerical value in Table (X2) at 5% significance level, confirms null hypothesis, which is a lack of non-homogeneous variance. Statistic t indicates significance of coefficients at 1%.

In the second stage of regression solution to equation (2), in the main equation, LE is replaced with its equivalent from equation

Table 1 *Coefficients in equation (4)*

$LE = \beta_0 + \beta_1 * MF$		
Variable	Coefficient	T-statistics
c	76.58	(41.21)*
MF	-3.12	(-3.11)*
R-squared= 0.27 Durbin-Watson= 2،47 LM(1)= 2،67 LM(2)= 2،80 White nR2= 0،65		
* p<0.01		

(4), as follows:

$$NG = \delta_0 + \delta_1 * MF + \delta_2 * (\beta_0 + \beta_1 MF) + \delta_3 * IM + \delta_4 * MM \quad (1\text{-}2)$$

Or

$$NG = (\delta_0 + \delta_2\beta_0) + (\delta_1 + \delta_2\beta_1) * MF + \delta_3 * IM + \delta_4 * MM \quad (1\text{-}1\text{-}2)$$

Equation 1-1-2 can be simplified as:

$$NG = \alpha_0 + \alpha_1 * MF + \alpha_2 * IM + \alpha_3 * MM \quad (5)$$

Equation (5) indicates regression relationship between natural growth rate (as dependent variable) and total marital fertility, and maternal and infant mortality rates (as explanatory variables). Results of coefficients α_3 وα_2،$\alpha_1$$\alpha_0$ and coefficients β_0 and β_1 can be used to obtain coefficients δ_4 وδ_3،δ_2،δ_1 δ_0 in equation (2) according to following equations:

$$\delta_0 + \delta_2\beta_0 = \alpha_0$$
$$\delta_1 + \delta_2\beta_1 = \alpha_1$$
$$\delta_3 = \alpha_2 \quad (1\text{-}5)$$
$$\delta_4 = \alpha_3$$

In finding regression coefficients from equation (5), variable of maternal death rate had to be eliminated due to incomplete statistics for 30 provinces. Elimination of regression coefficient α_3 from equation (5) meant elimination of δ_4 from equation (2) and λ_4 from equation (1). Results of regression coefficients α_2، وα_1،α_0 in equation (5) are shown in Table 2.

In Table 2, Durbin-Watson statistic can also confirm a lack of correlation in the model. However, LM (1) and LM (2) tests

Table 2 *Regression coefficients results in equation (5)*

$NG = \alpha_0 + \alpha_1 * MF + \alpha_2 * IM$		
Variable	Coefficient	T-statistics
C	-0،45	(-386.)*
MF	1،06	(1816 .)*
IM	-0،006	(-2،77)**
R-squared= 0.93 Durbin-Watson= 1،74 LM(1)= 0،001 LM(2)= 0،23 White nR2= 4.68		
* p<0.01 ** p<0.05		

for 1st and 2nd correlation ranks, compared to critical numerical value in Table (X2) at 5% significance level, confirm a lack of correlation up to the 2nd rank. White nR2 test, compared to critical numerical value in Table (X2) at 5% significance level, confirms null hypothesis, which is lack of non-homogeneous variance. Statistic t indicates significance of coefficients at 1% and 5% levels.

Given all the above, results of equation (5) coefficients are statistically confirmed. Now, there is a major problem in 1-5 equations, which is having three unknowns δ_2، وδ_1،δ_0 in two equations $\delta_0 + \delta_2\beta_0 = \alpha_0$ and $\delta_1 + \delta_2\beta_1 = \alpha_1$, despite knowing parameters α_1، وα_0،β_1،β_0. These three unknowns are found as follows:

In equation (2), $\delta_1 + \delta_2$ equals sum of ratios of changes in natural growth rate to changes in total marital fertility and changes in life expectancy:

$$\delta_1 + \delta_2 = (\Delta NG / \Delta MF) + (\Delta NG / \Delta LE)$$

But according to equation (5):

$$\frac{\Delta NG}{\Delta MF} = \alpha_1 \qquad (A)$$

And according to equation (4):

$$\frac{\Delta LE}{\Delta MF} = \beta_1 \qquad (B)$$

And $\Delta LE = \beta_1 * \Delta MF$

Using (A) and (B), we have:

$$(\Delta NG / \Delta MF) + (\Delta NG / \Delta LE) = \left(\frac{\Delta NG}{\Delta MF}\right) + \left(\frac{\Delta NG}{\beta_1 * \Delta MF}\right) = \frac{(\beta_1 * \Delta NG) + \Delta NG}{\beta_1 * \Delta MF}$$

$$= \frac{(\beta_1 + 1) * \Delta NG}{\beta_1 * \Delta MF} = \frac{(\beta_1 + 1)}{\beta_1} * \left(\frac{\Delta NG}{\Delta MF}\right)$$

$$(\Delta NG / \Delta MF) + (\Delta NG / \Delta LE) = \frac{(\beta_1 + 1)}{\beta_1} * \alpha_1$$

Therefore:

$$\delta_1 + \delta_2 = \frac{(\beta_1 + 1)}{\beta_1} * \alpha_1 \qquad (C)$$

Now using (C), and the first two equations in (1-5) can be written as three equations for three unknowns $\delta_2, \delta_1, \delta_0$ as follows:

$$\delta_0 + \delta_2\beta_0 = \alpha_0 \qquad (2\text{-}5)$$

$$\delta_1 + \delta_2\beta_1 = \alpha_1$$

$$\delta_1 + \delta_2 = \frac{(\beta_1 + 1)}{\beta_1} * \alpha_1$$

Using coefficients found from equations (4) and (5) for parameters $\alpha_2, \alpha_1, \alpha_0, \beta_1, \beta_0$, results of coefficients $\delta_2, \delta_1, \delta_0$, in equations (2-5), and $\delta_3 = \alpha_2$ in equations (1-5), the following result is obtained.

Using results in Table 3 and equations (3), coefficients in equation (1) can be found as follows:

Table 4

Using results in Table 4, the main equation (equation 1) for the revised life expectancy based on three main indices of total fertility rate, natural growth rate, and under 5 mortality rate can be written as:

Table 3 *Coefficients in equation (2)*

Parameters	Estimated
$\delta_0\delta_0$=	5.9
$\delta_1\delta_1$=	0.801
$\delta_2\delta_2$=	-0.083
$\delta_3\delta_3$=	-0.006

Table 4 *Coefficients in equation (1)*

Parameters	Estimated
$\lambda_0 = \left(-\frac{\delta_0}{\delta_2}\right)$	71.08
$\lambda_1 = \left(-\frac{\delta_1}{\delta_2}\right)$	9.65
$\lambda_2 = \left(\frac{1}{\delta_2}\right)$	-12.048
$\lambda_3 = \left(-\frac{\delta_3}{\delta_2}\right)$	-0.072

Results

Based on equation (1-A), revised life expectancy index in different provinces for 2009, compared to its initial numerical value in 2006 is shown in Table 5.

According to results presented in Table 5, numerical value of 2009 life expectancy in provinces based on important vital indices, compared to its initial value in 2006, shows some differences in ranking of provinces between these two years. With access to life expectancy at birth for different provinces in 2009, the differences in rankings could be better explained. Generally, according to Table 5,

Table 5 *Improved life expectancy index, by provinces for 2009 and life expectancy for 2006*

Row	Province	The revised Life expectancy index in 2009	Primary indicator of life expectancy in 2006	Change in status in 2009 compared to 2006
1	Sistan and Baluchestan	67.76	66.65	Improved
2	Hormozgan	69.12	68.7	Improved
3	Golestan	69.58	71.2	Reduced
4	Khuzestan	69.59	71.85	Reduced
5	Qom	69.64	73.2	Reduced
6	Kerman	69.68	70.4	Reduced
7	Bushehr	69.72	71.15	Reduced
8	Chahar	69.80	70.55	Reduced
9	Kohgilouyeh	70.08	68.6	Improved
10	W- Azerbaijan	70.14	70.95	Reduced
11	Elam	70.18	66.8	Improved
12	Qazvin	70.45	72.5	Reduced
13	Zanjan	70.46	70.5	Reduced
14	Lorestan	70.47	69.7	Improved
15	Kermanshah	70.79	70.2	Improved
16	Fars	70.93	72.15	Reduced
17	Tehran	71.07	74.7	Reduced
18	Kurdistan	71.25	66.5	Improved
19	Isfahan	71.31	74.7	Reduced
20	Hamedan	71.38	70.1	Improved
21	Ardebil	71.38	70.25	Improved
22	E-Azerbaijan	71.40	71.95	Reduced
23	Khorasan	71.69	70.5	Improved
24	Central	72.38	71.65	Improved
25	Mazandaran	73.44	71.8	Improved
26	Yazd	73.84	73.4	Improved
27	Semnan	74.44	72.95	Improved
28	Gilan	75.18	71.8	Improved
Weighted mean country		71.02	71.77	Reduced

taking into account the effect of vital indices (which also include effect of state interventions), with a revised statistical-analytical life expectancy at birth, a rational relationship can be established between this and vital indices, and the effect of interventions can be shown by adjustments in life expectancy index.

Discussion

Life expectancy, as an important indicator of health status, is considered one of the important data in studying health sector development and assessing the effect of interventions in this sector. In many studies, the importance of life expectancy has been attributed to statistical correlation between it and development indices. In his study, Ikeda believes high life expectancy in Japan is due to development of equal economic opportunities and public health in the rapid economic growth during 1960s and 1970s, and shows that reduced under 15 mortality rate and fertility rate after 1950s led to increased elderly population over 60 years of age, and also Japan ranked among economically developed countries. Moreover, with an appropriate health cost in 2010, equivalent to 8.5% of GDP, Japan had very low socioeconomic inequities in different geographical regions compared to other developed countries. Yet, inequities in income, especially since early 1990s and recession periods in Japan are gently rising. In this study, differences in life expectancy in different areas were found to be significantly related to economic inequities and differences in mortality and fertility rates[3]. In another study by Makinbak, increased life expectancy and reduced mortality rates were shown to be related to changes in political tendencies in transition to democracy and political conditions in already democratic countries. In this study, the reducing trend of mortality widely varied between 1920s and 1960s in the Eastern Bloc countries, and in the following years, state interventions to increase life expectancy and control rising mortality due to cardiac diseases, cancer, and other non-infectious diseases and accidents were considered highly influential. In democratic countries, such interventions have also become more or less dependent on political conditions[9]. In a study in England and Wales, over a long period 1840-2000, using regression model, José Granados showed an inverse relationship between economic growth and increased income and increased life expectancy due to reduced mortality rate. This meant that, mortality rate decreases in periods of reduced income, and life expectancy from birth increases. This relationship can only be explained by the behavior of variables used in the model[10].

In a study by Hertz et al., in an international comparison, based on data from the Food and Agriculture Organization (FAO) affiliated to the United Nations and the World Health Organization and the World Bank in 66 countries, variables of life expectancy, under 5 mortality and maternal mortality rates were considered independently from one another, and each was assessed separately in regression models against explanatory variables, including access to safe water, environmental sanitation, protein nutrition, calories and fat intake, and socioeconomic variables, including growth in workforce, access to healthcare, and literacy rate. After eliminating very poor countries and effects of beliefs and cultures, the results showed that increased life expectancy and reduced mortality rates were caused by intersectoral development and interventions to promote health [11]. Jaba et al. classified 193 countries in terms of income and geographical area, and studied the effects of time, geographical and income differences on life expectancy, and concluded that life expectancy has increased over two decades in various countries. This improvement was affected by geographical differences and health systems and objectives determined for these systems [12]. In a study presented in 2005, aiming to compile a national program to reduce health access inequities in England, a practical program, taking into account the effect of a set of socioeconomic and medical/health interventions on reduced mortality and disease rates, resulted in the need for increased life expectancy and changes in life Table [13]. Joshua Salomon et al. in their study on life expectancy in 178 countries over 1990-2010, used data from disease burden studies in this period, and showed that in the past 20 years, for every one year increase in life expectancy, Health Adjusted Life Expectancy (HALE) has only increased by 10 months. The difference is due to increased life expectancy of people with disability, and shows that concurrent interventions with reduced mortality rates have paid little attention to reducing effects of disease on healthy life[14].

While emphasizing the relationship between life expectancy index and health sector development, these studies generally consider increased life expectancy according to diet, lifestyle, and interventions to increase access to medical care and avoidance of chronic fatal diseases. In the last few decades, interventions aiming to prevent under 5 mortality, maternal mortality due to labor complications, and under 20 or 25 year mortality, have been associated with increased life expectancy. Studies conducted in Iran have also emphasized life expectancy as an indicator of general health status, and presented its results with a wide range of data relating to life Table, population assumptions, estimates of life and death in different age groups [15-18] ,. This study also attempted to provide estimates for disease burden index, disability, and health adjusted life expectancy in different age groups using life Table.

Conclusion

The present study results show revised life expectancy based on adjustment with vital indices of total fertility rate, natural growth rate, and under 5 mortality rates as indices affected by state interventions in Iran. According to these results and equation (1-A), it can be expected that in Iran, with every unit of increase in each of the three indices, life expectancy will increase or decrease with coefficients +9.56, -12.048, and -0.072, respectively. Thus, state interventions to improve vital indices can also be shown with quantitative results in changes in life expectancy years. The minor difference between mean national revised index and initial index indicates very high percentage of explanatory power of revised national index by equation (1-A). The differences between these two indices in each province, shown by improved or reduced status, can be indicative of statistical problems in calculation of life expectancy at birth, which also leads to impaired explanation of influence of state interventions through improved vital indices on increased life expectancy.

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Contribution

Study design: MK, ET
Data collection and analysis: MK, ET
Manuscript preparation: MK, ET

Conflict of Interest

"The authors declare that they have no competing interests."

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