**Exploring Life Expectancy:   
A Comprehensive Analysis of Modern Medicine   
and the Life Cycle Allocation Theory**

Acacia Johnson

Department of Accounting, Finance, and Economics

Tarleton State University

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Dr. Watson

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Abstract

Panel data consisting of life expectancy factors is analyzed internationally. It is found through the effects of healthcare that the Life-Cycle Allocation Theory is proven true. Total expenditures in healthcare on younger individuals is proven to positively affect life expectancy. As more variables are added, total expenditures loses its significance. Healthcare ( through immunization rates) does have a positive impact of life expectancy.

Keywords: Healthcare, Life-cycle Allocation Theory, Fixed-Effects

**Introduction**

There are several influences on how long an individual can expect to life, also known as their life expectancy. Modern medicine plays a significant role in positively improving that. With that in mind, this paper uses the life-cycle allocation theory to analyze how societies distribute healthcare throughout the individual’s life.

These two concepts provide a strong image on how each country has their own life expectancy. In the past century, breakthroughs in medicine have allowed the severity of health issues to diminish. Internationally, new drugs and improved surgery methods have treated various diseases.

Roser analyzes international data from the last two centuries to determine how life expectancy has evolved over time. There are four main conclusions from the study. First, life expectancy has grown to be as twice as long. Second, life expectancy has positively improved around the globe. Third, life expectancy is increasing at a steady rate. Finally, life expectancy has increased across all countries.

At the beginning of the 19th century, an individual’s expected life was only 40 years old. Improvements in medicine have lower child mortality rates and extended older individuals. For each improvement, the advancement of medicine seen in the last 200 seen years as had positive effects across the globe (Ho, 2022). Instead of a stagnant life expectancy, there is proof of a positive linear effect (excluding COVID-19). Interestingly, Japan has the highest life expectancy in 2021 by at least 10 years, the second closest being Oceania.

The dataset uses percentage expenditure (a percentage of health on GDP per capita), total expenditure (general government expenditure on health as a percentage of total government expenditure), and gross domestic product (GDP) as measurements of allocation.

The comprehensive exploration of both modern medicine and life-cycle allocation theory influences how long an individual will live in modern times. Using knowledge from the fields of medicine, sociology, and public health, I aim to contribute an explanation for the length and quality of human life, The goal of this study is to provide evidence to inform policy decisions that will support fair and healthy opportunities internationally.

**Life-Cycle Allocation Theory**

The life-cycle allocation theory implies that the distribution of resources at certain stages of age impact the average life expectancy (Ghez and Becker, 1975”). Each country has a different method to allocate resources. One country may allocate more funds into education for younger individuals, while another country might distribute more healthcare resources for the elderly. The varying distribution will inevitably influence life expectancy.

The crucial point of the life-cycle allocation theory is that each life stage has different resources dispersed. What this study strives to explain is how certain resources, i.e., healthcare and education, can contribute to a longer life expectancy. “This decrease is a historic change in the development of worldwide health status, and such a sustained trend has never been seen before for national populations…”(Mathers et al., 2015). As mentioned earlier, choosing to distribute more educational resources to younger individuals may provide an appropriate health foundation for later stages. Allocating healthcare and medicine to later stages may prolong an individual’s life expectancy.

This leads me into my next point. The life-cycle allocation theory can point out how variations in the amount of available medicine can impact one’s overall health. “The age at which Americans begin experiencing a mortality advantage relative to other countries has been pushed back to progressively older ages”(Ho, 2022 ). This can provide less benefit and more consequences than intended. Each demographic group has its own disparity in healthcare and medicine.

Another look at the theory is how the elderly stages will face a challenging time medically while maintaining a professional career. It is an expectation for those in later stages of life to retire from their chosen career field. In today’s economy, there is a staggering number of people unable to sustain the same economic productivity as in earlier life stages. “The average worker in the sample is observed in the middle of work life, when relative age-earnings growth has mostly disappeared and subsequent living standards are largely set” (Roser, 1988). We, as a society, will have expectations on how our later years will turn out. By the midlife point, living standards will remain stagnant. We can combat this stagnancy through health spending ( in the form of immunizations) for the young and support programs such as Social Security for the elderly.

**Methodology**

**Fixed Effects vs. Random Effects vs. Pooled Effects**

The following results will use the fixed effects model for each, as opposed to random effects or pooled effects. There are multiple constants (the country) with differing years. The only change in the data is the year recorded. Keeping a constant in the data allows for comparisons between each country in a certain year.

To determine if the random effects model is appropriate, a ‘Test for differing group intercepts’ will be performed for each regression. The test establishes if fixed effects is a more appropriate fit than random effects and pooled effects for the regression. The ‘Test for differing group intercepts’ will conclude if the variable estimates are consistent. Any test with a p-value greater than 0.05 has consistent estimates. If the test returns inconsistent estimates the fixed-effects model will be used. For each regression in this study, the test returns inconsistent estimates where the p-value is less than 0.05.

For all three instances, the pooled effects model will not be utilized. Pooled effects is performed in a regression due to the added effects of new variables. Usually, large sets of data are interpreted in a broader sense to account for more than one changing variable. In this study, the only change for each observation, besides country, is the year.

**Variables**

The dataset was obtained through the World Health Organization (WHO) and presented in a panel format. It was aggregated through Kaggle. Each variable uses a numerical value or a dummy variable. The variable of variable of interest is total expenditures. There are various countries (over 3000 observations) recorded from 2000-2012 with each variable. Due to the recency of some data, there are empty values in some of the medical variables. The dataset includes several diseases and health factors to measure the effect of modern medicine. Diphtheria, Hepatitis B, and Polio are some of those factors. All variables used in the dataset are listed below with their definition.

|  |  |
| --- | --- |
| **Variable** | **Definition** |
| Country | Dummy variable. |
| Life Expectancy | Dummy variable. Age in years |
| Adult Mortality | Adult Mortality Rates of both sexes (probability of dying between 15 and 60 years per 1000 population) |
| Infant Deaths | Number of Infant Deaths per 1000 population |
| Percentage Expenditure | Expenditure on health as a percentage of Gross Domestic Product per capita (%) |
| Hepatitis B | Immunization coverage among 1-year-olds (%) |
| Under Five Deaths | Number of under-five deaths per 1000 population |
| Polio | Immunization coverage among 1-year-olds (%) |
| Total Expenditures | General government expenditure on health as a percentage of total government expenditure (%) |
| Diphtheria | Immunization coverage among 1-year-olds (%) |
| GDP | Gross Domestic Product per capita (in USD) |
| Population |  |
| Schooling | Number of years of Schooling(years) |

**Influences**

Mathers starts by introducing their results, Life expectancy is stable in a few countries for both men and women, Countries with higher incomes, have seen a positive correlation to an increasing life expectancy. In addition, there is no evidence the rate of improvement is slowing down. The data in this article is retrieved from the WHO, starting in the year 1990 and ending in 2012. This data shares a 12-year time segment with my own personal data. This means the results seen from Mathers should be like the ones I find.

When preforming the regressions, Mathers splits each result based on gender and region. This gives the researchers the opportunity to analyze how exactly geographic location and sex impact life expectancy. One more key factor about the data is the age range. Mathers only used data from people 50 years and older. The assumption that most individuals will live to 50 years. Child death is not included and eliminates the need for any outliers.

Rosen uses life-cycle allocation theory to estimate the inherent value of life. Changes in an age-specific mortality risk affects the entire function and changes consummation and labor supply in the entire cycle. Based on multiple cross-sectional regressions, life values decrease between the current age and the age of risk. This means an older person is receives more benefits from healthcare than a younger person. A younger person may need healthcare on average, but not at the same severity of later life stages.

Since there is not a direct method to determine the value of life, Rosen uses Two-Stage Least Squares. The instrumental variable is “the probability of surviving to any given age.” The first formula is the conditional probability of surviving until age *t* given that one has survived until age *a*. The second stage uses expected utility as the *y* variable. This formula expects the individual has survived until age *a* (Rosen, 1988) . While I would like to use Two-Stage least squares, it is more effective to perform a f-test on the added healthcare variables. There are too many variables with differing meanings to combine into one group. Dues to this, I will only be focusing on immunizations as a form of medicine.

**Hypotheses**

There are three main hypotheses for life expectancy in this study. The first prediction strives to determine if total expenditures on health have a positive effect of life expectancy. In accordance with Rosen, the life-cycle allocation theory is broken down into its basic form: more allocated resources increase life expectancy. This is represented by the equation:

The second hypothesis investigates if total expenditures is still significant with the inclusion of other general variables. The regression will include total expenditure, adult mortality, deaths under five years old, schooling, and GDP. The regression strives to explain the how much total expenditures affects life expectancy with the inclusion of other variables.

The third hypothesis will focus on medicine’s effect on life expectancies. As mentioned in Roser’s analysis of international life expectancies, modern medicine may decrease the number of deaths in a country. Hepatitis B, Polio, and Diphtheria immunizations are the focus for medicine. If a country can vaccinate a substantial portion of the 1-year-olds, the chance for future deaths from these diseases decrease. The thought process behind this regression is to set up a f-test to explain if medicine will increase life expectancy.

**Results**

**Univariate**

Model 1: Fixed-effects, using 2702 observations

Included 181 cross-sectional units

Time-series length: minimum 3, maximum 16

Dependent variable: Life expectancy

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | *Coefficient* | *Std. Error* | *t-ratio* | *p-value* |  |
| const | 68.5852 | 0.195049 | 351.6 | <0.0001 | \*\*\* |
| Total expenditure | 0.107923 | 0.0317741 | 3.397 | 0.0007 | \*\*\* |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Mean dependent var | 69.22524 |  | S.D. dependent var | 9.529783 |
| Sum squared resid | 17293.90 |  | S.E. of regression | 2.619668 |
| LSDV R-squared | 0.929498 |  | Within R-squared | 0.004557 |
| LSDV F(181, 2520) | 183.5557 |  | P-value(F) | 0.000000 |
| Log-likelihood | −6341.917 |  | Akaike criterion | 13047.83 |
| Schwarz criterion | 14121.95 |  | Hannan-Quinn | 13436.25 |
| rho | 0.705982 |  | Durbin-Watson | 0.520524 |

Joint test on named regressors -

Test statistic: F(1, 2520) = 11.5367

with p-value = P(F(1, 2520) > 11.5367) = 0.000692935

Test for differing group intercepts -

Null hypothesis: The groups have a common intercept

Test statistic: F(180, 2520) = 175.131

with p-value = P(F(180, 2520) > 175.131) = 0

The model above uses an univariate regression to describe the effects of total expenditure on life expectancy. Since the p-value on ‘Test for differing group intercepts’ is less than 0.05, I can safely reject that the groups have a common intercept. Therefore, the fixed effects model is appropriate to use. As predicted in the methodology section, it is statistically significant at the 99% confidence level. The average person lives for 68.5 years without any help from government spending. For each additional percentage point in total expenditure, life expectancy is expected to increase by 0.10 years, on average.

**Multivariate**

Model 2: Fixed-effects, using 2327 observations

Included 157 cross-sectional units

Time-series length: minimum 3, maximum 16

Dependent variable: Lifeexpectancy

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | *Coefficient* | *Std. Error* | *t-ratio* | *p-value* |  |
| const | 61.0775 | 0.549935 | 111.1 | <0.0001 | \*\*\* |
| Totalexpenditure | 0.0351654 | 0.0302042 | 1.164 | 0.2444 |  |
| AdultMortality | −0.00402836 | 0.000597465 | −6.742 | <0.0001 | \*\*\* |
| underfivedeaths | −0.00844574 | 0.00142598 | −5.923 | <0.0001 | \*\*\* |
| Schooling | 0.737210 | 0.0409343 | 18.01 | <0.0001 | \*\*\* |
| GDP | 1.60719e-05 | 5.28741e-06 | 3.040 | 0.0024 | \*\*\* |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Mean dependent var | 69.25733 |  | S.D. dependent var | 9.692745 |
| Sum squared resid | 11936.47 |  | S.E. of regression | 2.348059 |
| LSDV R-squared | 0.945377 |  | Within R-squared | 0.189476 |
| LSDV F(161, 2165) | 232.7365 |  | P-value(F) | 0.000000 |
| Log-likelihood | −5204.214 |  | Akaike criterion | 10732.43 |
| Schwarz criterion | 11664.31 |  | Hannan-Quinn | 11071.98 |
| rho | 0.609966 |  | Durbin-Watson | 0.688042 |

Joint test on named regressors -

Test statistic: F(5, 2165) = 101.222

with p-value = P(F(5, 2165) > 101.222) = 3.86073e-096

Test for differing group intercepts -

Null hypothesis: The groups have a common intercept

Test statistic: F(156, 2165) = 55.249

with p-value = P(F(156, 2165) > 55.249) = 0

Model 2 investigates the effects of death rates in various age categories. Each variable, except for total expenditure, is statistically significant at the 99% confidence level. Since the p-value is zero, fixed effects is better than pooled effects. The added effect of GDP takes into account a country’s economic health. It is the market value of all finish products over a year. When added into the regression, total expenditures losses all significance. While its effect on life expectancy is small, GDP acts as a control for income and wealth a country earns.

Adult mortality and deaths under 5 years old decrease life expectancy. Per every 1000 deaths of under 5-year-olds, life expectancy decreases by 0.008 years, holding all else constant. For each additional average year in schooling, the population can expect to live 0.74 years longer, ceterus paribus.

**Immunization Effects**

Model 3: Fixed-effects, using 1863 observations

Included 148 cross-sectional units

Time-series length: minimum 1, maximum 16

Dependent variable: Lifeexpectancy

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | *Coefficient* | *Std. Error* | *t-ratio* | *p-value* |  |
| const | 60.3711 | 0.712219 | 84.76 | <0.0001 | \*\*\* |
| Totalexpenditure | 0.0532411 | 0.0308717 | 1.725 | 0.0848 | \* |
| AdultMortality | −0.00389124 | 0.000641798 | −6.063 | <0.0001 | \*\*\* |
| underfivedeaths | −0.00652627 | 0.00185646 | −3.515 | 0.0005 | \*\*\* |
| Schooling | 0.710426 | 0.0507755 | 13.99 | <0.0001 | \*\*\* |
| GDP | 1.97061e-05 | 5.63363e-06 | 3.498 | 0.0005 | \*\*\* |
| HepatitisB | 0.0103710 | 0.00282697 | 3.669 | 0.0003 | \*\*\* |
| Diphtheria | 0.00663375 | 0.00349282 | 1.899 | 0.0577 | \* |
| Polio | −0.000815492 | 0.00311430 | −0.2619 | 0.7935 |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Mean dependent var | 69.99512 |  | S.D. dependent var | 8.605838 |
| Sum squared resid | 7159.192 |  | S.E. of regression | 2.047931 |
| LSDV R-squared | 0.948084 |  | Within R-squared | 0.183712 |
| LSDV F(155, 1707) | 201.1180 |  | P-value(F) | 0.000000 |
| Log-likelihood | −3897.476 |  | Akaike criterion | 8106.952 |
| Schwarz criterion | 8969.624 |  | Hannan-Quinn | 8424.845 |
| rho | 0.577921 |  | Durbin-Watson | 0.750756 |

Joint test on named regressors -

Test statistic: F(8, 1707) = 48.0217

with p-value = P(F(8, 1707) > 48.0217) = 3.7681e-070

Test for differing group intercepts -

Null hypothesis: The groups have a common intercept

Test statistic: F(147, 1707) = 49.42

with p-value = P(F(147, 1707) > 49.42) = 0

To explain the effect of medicine, I will add in three measures of immunizations percentages for each county’s population. Total expenditures on health regains significance at the 90% confidence level, while the only non-significant variable is Polio immunizations. For each additional percentage increase in Hepatitis B immunizations, life expectancy increases by 0.01 years, ceterus paribus. Total expenditure increases life expectancy by 0.05 years, holding all else constant. For each additional percentage increase in Diphtheria immunizations, life expectancy increases by 0.007 years, ceterus paribus. Since Polio immunizations have no significance, it can be inferred that all other variables are able to explain life expectancy.

This is where I will perform a f-test between model 2 and model 3. With a f-statistic of 32.22 and a critical value of 2.097, I can safely reject my null hypothesis that healthcare ( in the form of immunizations) has zero effect on the average life expectancy. To distribute more immunizations, the number of total expenditures spent on healthcare needs to increase. This proves countries that focus on immunization measures towards children can expect their population to live longer lives. In conclusion, wealthier countries have the resources to treat more young people which leads to longer life expectancies.

**Conclusion**

The life-cycle allocation theory provides the necessary tools to understanding how resources impact global life expectancy. This analysis looks at individual life stages to determine if there are any valuable insights to be gained from government spending, healthcare, and education. The results prove there is a tangible reason for policy makers to consider this economic concept.

Total expenditures, which is general government expenditure on health as a percentage of total government expenditure is a straightforward way to understand the effect of healthcare. Based on model 2 , the hypothesis that total expenditures increase life expectancy is semi-correct. The added effect of GDP controls for income in each country. It can be restated that countries with more income have more resources to allocate to healthcare.

As expected, adult and child mortality decrease the life expectancy average. When adding the effects of healthcare, there is a noticeable difference in life expectancy. A lack of immunizations will have a negative impact on life expectancy, while the vice versa is true. This proves that the third hypothesis that medicine has a positive impact on life expectancy.

# References

Ghez, Gilbert, and Gary S. Becker. “The Allocation of Time and Goods over the Life Cycle.” NBER, 1975. <https://www.nber.org/books-and-chapters/allocation-time-and-goods-over-life-cycle>.

Ho, J. Y. (2022). Causes of America’s Lagging Life Expectancy: An International Comparative Perspective. *The Journals of Gerontology: Series B*, *77*(Supplement\_2), S117–S126. <https://doi.org/10.1093/geronb/gbab129>

*Life Expectancy (WHO)*. (n.d.). Retrieved October 31, 2023, from <https://www.kaggle.com/datasets/kumarajarshi/life-expectancy-who>

Mathers, C. D., Stevens, G. A., Boerma, T., White, R. A., & Tobias, M. I. (2015). Causes of international increases in older age life expectancy. *The Lancet*, *385*(9967), 540–548. <https://doi.org/10.1016/S0140-6736(14)60569-9>

Rosen, S. (1988). The value of changes in life expectancy. *Journal of Risk and Uncertainty*, *1*(3), 285–304. <https://doi.org/10.1007/BF00056139>

Roser, M., Ortiz-Ospina, E., & Ritchie, H. (2013). Life Expectancy. *Our World in Data*. <https://ourworldindata.org/life-expectancy>