

Okunade, Albert; Osmani, Ahmad

Article — Manuscript Version (Preprint)

Effects of life expectancy on economic growth: New results using the flexible Box-Cox power transformation model

Applied Economics Letters

Suggested Citation: Okunade, Albert; Osmani, Ahmad (2020) : Effects of life expectancy on economic growth: New results using the flexible Box-Cox power transformation model, Applied Economics Letters, ISSN 1466-4291, Taylor & Francis, London, Iss. Latest Articles, <https://doi.org/10.1080/13504851.2020.1713976> , <https://www.tandfonline.com/doi/full/10.1080/13504851.2020.1713976>

This Version is available at:

<https://hdl.handle.net/10419/211089>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

Effects of life expectancy on economic growth: New results using the flexible Box-Cox power transformation model

Abstract

This article revisits the effects of life expectancy (LE) on economic growth (IPC) reported in previous research. Maximum likelihood (ML) estimates are obtained based on the monotonic nonlinear flexible Box-Cox power transformation regression model. This variance stabilizing model, unlike the *a priori* restrictive nested log and linear forms, is a parametrically richer flexible functional form for transforming the dependent and independent variables separately with different power parameters. The conditional life expectancy elasticity of income estimates are found to vary across fitted models and the more robust flexible Box-Cox power model outperforms the restrictive linear and log specifications fitted in past work. Contrary to past findings indicating large negative and highly elastic (statistically significant) life expectancy (LE) elasticity of income (INC), new results from the preferred fully flexible Box-Cox model incorporating the nonlinear effect yield a much smaller negative (statistically significant) and inelastic life expectancy elasticity of income estimate. Study explores some policy options for enhancing economic growth during periods of high or rising life expectancy.

Keywords: flexible Box-Cox transformation; non-linearity; life expectancy; economic growth; elasticity

JEL classification: I1, O1

Conflicts of Interest Declaration: None

1. Introduction

In a novel contribution, Acemoglu and Johnson (2007, hereafter AJ) find that increases in life expectancy (LE) arising from the epidemiological revolution of the 1940s could not raise income per capita. The study's instrumental-variables (IVs) estimates confirm the diminishing effects of LE on income per capita (IPC). Contrasting an extensive body of work (Azariadis and Drazen, 1990; Durlauf and Johnson, 1995; Cervellati and Sunde, 2011), AJ's identification strategy assumed a linear LE effect on economic growth (IPC). Desbordes (2011), in attempting to improve on the functional form model specification in the AJ study, tested the non-linear effects of LE on IPC by including a log-transformed quadratic term ($\log \text{INC}^2$) in the economic growth equation. However, the log transformation is also a restricted form nested in a more flexible specification.

Therefore, this paper proposes specification and estimation of the parametrically richer Box-Cox (Box and Cox, 1964) power family model, where the left and right hand side variables of interest are transformed with different transformation exponents. The variance stabilizing Box-Cox methodology normalizes the regression model residuals (Greene, 2011) and several studies (Okunade, 1992; Jones, 2017) confirm its usefulness for reducing functional form specification error. Moreover, there are recent calls in the social sciences for more replication studies (Camerer, Dreber and Forsell, 2016) to test robustness of empirical research and policy suggestions (Hamermesh, 2017; Kiri, Lacetera and Zirulia, 2018). However, Begley and Ioannidis (2015) caution investigators on the complexities inherent in replication. Replication in economics and allied business disciplines (Hubbard and Vetter, 1996), in the broad or narrow sense (Pesaran, 2003), can advance reliability of scientific discourse from a social welfare and policy viewpoint (Kiri, Lacetera and Zirulia, 2018). Therefore, we first replicate two major studies on the effects of

life expectancy on economic growth in 47 countries, then propose and estimate the more flexible Box-Cox (FBC) functional form model to test robustness.

This study results reveal highly statistically significant parameter estimates of the non-linear FBC model. Second, the new findings from the FBC empirical modeling strategy incorporating the quadratic life expectancy effect yields -0.87 estimate (statistically significant) of the life expectancy elasticity of per capita income. This contrasts sharply with the -1.32, -9.44, and -10.83 elasticity estimates from the replicated past studies (see, Table 1). Third, the new findings reject the restricted functional form models in past work. Finally, these findings caution applied economists on the importance of selecting appropriate estimating functional form models.

2. Material, Methods, Results and Discussion

Using 1940-1980 data covering 47 countries at different stages of development and panel data modelling, AJ's original paper specified and empirically estimated the equation:

$$\ln (IPC)_{it} = \gamma_0 + \gamma_1 \ln (LE)_{it} + \eta_i + \kappa_t + \varphi_{it} \quad (1)$$

where, IPC is income per capita and LE is the life expectancy of country i at time t , respectively. Moreover, η_i and κ_t are country and time specific fixed effects and φ_{it} is the idiosyncratic error term. It is worth mentioning that first-differenced or fixed effects estimators provide similar results given that there are two time periods while a log-difference estimation is equivalent to AJ's IV method. Replication study findings are important in scientific economics discourse (Hamermesh, 2017). We first replicate (col. 1, Table 1) AJ's IV results using their dataset. The time-invariant instrument is an interaction term constructed by the dates of disease-specific global intervention and country-specific disease prevalence. The IV results affirm the negative effects of LE on IPC.

Desbordes (2011) improved on the AJ model specification by incorporating the quadratic term¹ of the LE variable and tested² its effect on IPC. Desbordes (2011) estimated the equation

$$\ln (IPC)_{it} = \gamma_0 + \gamma_1 \ln (LE)_{it} + \gamma_2 [\ln(LE)]^2 + \eta_i + \kappa_t + \varphi_{it} \quad (2)$$

For comparison with estimates of our proposed model, we also replicate and report results using the Desbordes (2011) model in columns (2) and (3) of Table 1 of the present paper. The statistically significant and positive coefficient estimate of the quadratic term in Eq. (2) confirms that LE has a negative effect on economic growth until reaching a threshold point after which the impact on per capita income is positive. The Ordinary Least Squares (OLS) estimates in Desbordes (2011) are homologous to the IV model results. Maximum likelihood (ML) parameter estimates of our FBC model results are in column 4, Table 1.

This study tests for possible existence of a parametrically richer and more flexible functional form for capturing the nonlinear effects of LE on IPC, by proposing for estimation an *a priori* more FBC power transformation model. This modelling strategy has several strengths compared with higher-order polynomial models of the Gaussian family. First, unlike the restrictive log-log model, the FBC model is a straightforward method for determining more precisely the degree of nonlinearity through λ (left hand side) and θ (right hand side) transformation exponents to yield flexible estimates of the non-linearity effect in the data generation process (Greene, 2011). The model estimation method is efficient and the transformation improves normality of the response variable and homoscedasticity of the residuals.

¹ The same interaction term with a quadratic form is used as instrument.

² Regression Equation Specification Error Test (RESET) and the Ramsey/Pagan-Hall statistical test justify the relevance of non-linearity in AJ's IV model.

Table 1. Effect of life expectancy on income per capita: Box-Cox versus IV and OLS models

| | Ln (GDP per capita) | | | Flexible Box-Cox θ transformed GDP per capita |
|---|---|---|--|--|
| | IV (1) (Replication of Acemoglu and Johnson, 2007) | IV (2) (Replication of Desbordes, 2011) | OLS (3) (Replication of Desbordes, 2011) | Box-Cox, MLE (4) |
| ln (life expectancy) | -1.316** (0.555) ¹ | -18.096** (9.08) | -21.13*** (4.33) | -- |
| ln (life expectancy) ² | -- | 2.314* (1.299) | 2.755*** (0.601) | -- |
| Box-Cox λ transformed life expectancy | -- | -- | -- | -5.8088*** (2.301) |
| Box-Cox λ transformed life expectancy squared | -- | -- | -- | 0.785*** (0.089) |
| Constant | 14.531*** (2.230) | 44.2651** (20.156) | 49.37*** (7.548) | 5.161*** (1.0564) |
| Number of observations | 94 | 94 | 94 | 94 |
| Number of countries | 47 | 47 | 47 | 47 |
| Adjusted <i>R-square</i> | 0.9220 | 0.9554 | 0.9797 | 0.9434 |
| λ (Right hand side transformation exponent) | -- | -- | -- | 4.132*** (0.292) |
| θ (Left hand side transformation exponent) | -- | -- | -- | -0.112*** (0.022) |
| Conditional estimate of Life Expectancy elasticity of income ² | -1.32** | -9.44* | -10.83*** | -0.87*** |

*, ** and *** indicate statistical significance at the 0.10, 0.05 and 0.01 levels, respectively.

¹Standard errors in parentheses.

² Estimated elasticity is conditional on each country's initial level of life expectancy. For the fully flexible Box-Cox model (col. 4), elasticity is calculated using the following expression derived by Thierry Nianogo, where $y=IPC$ and $x=LE$.

$$\frac{\partial y}{\partial x} * \frac{\bar{x}}{\bar{y}} = \left[\left(\frac{\theta \gamma_1}{\theta} + \frac{2\gamma_2}{\theta} \right) x^{(\theta-1)} + \frac{2\gamma_2}{\theta} x^{(2\theta-1)} \right] \left[\frac{y^{\lambda-1}}{\lambda} + 1 \right] * \frac{\bar{x}}{\bar{y}}. \text{ Details obtainable from authors by request.}$$

The empirical model proposed and econometrically estimated is

$$[IPC]_{it}^{(\lambda)} = \gamma_0 + \gamma_1 (LE)^\theta + \gamma_2 [(LE)^2]^{(\theta)} + \eta_i + \kappa_t + \varphi_{it} \quad (3)$$

where, the dependent variable and independent variable of interest are transformed using λ and θ parameters, respectively. The preferred FBC model estimates (column (4), Table 1) are tested against the log ($\theta = \lambda = 0$) and linear ($\theta = \lambda = 1$) functional form models using the log-likelihood ratio χ^2 test statistic. The data rejected restricted functional form models and detected statistical significance for both transformation exponents of preferred FBC model. The dominance of the FBC modelling strategy suggests its appropriateness as a parametrically richer power family of transformations model for capturing more precisely the nonlinear effects of life expectancy on economic growth. Surprisingly in sharp contrast to past studies, the statistically significant -0.87 life expectancy elasticity of income estimate from the preferred FBC model is inelastic. This implies that the continuing rise in life expectancy (with greater investments in education and labor force participation) is increasingly accompanied by costly chronic disease burdens and disabilities at older ages that reduce labor market participation of the ageing work force and per capita productivity of resources.

Study findings suggest some public policy measures to strengthen economic growth when life expectancy is high and rising. First, the adverse effect of higher life expectancy on economic growth could be reduced through improved immigration policies targeting the relatively younger and well-educated unemployed and underemployed migrants from other countries. Second, as in post-war Japan (Johansson and Mosk, 1987), greater and more effective public health investments could raise healthy life expectancy years and productivity of the ageing workforce. Third, gradual softening of mandatory retirement laws could raise workforce participation and economic growth.

3. Summary and Conclusion

This paper revisits the life expectancy effects on economic growth using the dataset on 47 countries in Acemoglu and Johnson (2007) and Desbordes (2011) and estimated the more flexible Box-Cox power transformation model (FBC) to test robustness of past findings fitting restrictive linear and log-log models. The new results incorporating the quadratic life expectancy effect yields an inelastic estimate of -0.87 life expectancy elasticity of per capita income. This contrasts sharply with the -1.32, -9.44, and -10.83 elasticity estimates from the replicated past studies.

References

- Acemoglu, D., and Johnson, S. (2007). Disease and development: the effect of life expectancy on economic growth. *Journal of Political Economy*, 115(6): 925-985.
- Azariadis, C., and Drazen, A. (1990). Threshold externalities in economic development. *The Quarterly Journal of Economics* 105(2): 501-526.
- Begley, C.G., and Ioannidis, P.A. (2015). Reproducibility in science. Improving the standard for basic and preclinical research. *Circulation Research* 116: 116-126.
- Box, G. E., and Cox, D. R. (1964). An analysis of transformations. *Journal of the Royal Statistical Society. Series B (Methodological)*, 26(2): 211-252.
- Camerer, C.F., Dreber, A., Forsell, E. *et al.* 2016. Evaluating replicability of laboratory experiments in economics. *Science* 351(6280): 1433-1436.
- Cervellati, M., and Sunde, U. (2011). Life expectancy and economic growth: the role of the demographic transition. *Journal of Economic Growth*, 16(2): 99-133.
- Desbordes, R. (2011). The non-linear effects of life expectancy on economic growth. *Economics Letters*, 112(1): 116-118.
- Durlauf, S. N., and Johnson, P. A. (1995). Multiple regimes and cross-country growth behaviour. *Journal of Applied Econometrics*, 10(4): 365-384.
- Greene, W. H. (2011). *Econometric Analysis*. 7th Ed. Boston, MA: Prentice Hall.
- Hamermesh, D.S. (2017). Replication in labor economics: evidence from data and what it suggests. *American Economic Review Papers & Proceedings*, 107 (5): 37-40
- Hubbard, R. and Vetter, D.E. (1996). An empirical comparison of published replication research in Accounting, Economics, Finance, Management and Marketing. *Journal of Business Research* 35(2): 153-164.
- Johansson, S.R. and Mosk, C. (1987). Exposure, resistance and life expectancy: disease and death during the economic development of Japan 1900-1960. *Population Studies*, 41(2): 207-235
- Jones, A.M. (2017). Data visualization and health econometrics. Foundations and Trends in Econometrics. <https://doi.org/10.1561/08000000033> White Rose University Consortium. University of Leeds, Sheffield and York. <http://eprints.whiterose.ac.uk/120147/>
- Kiri, B., Lacetera, N., and Zirulia, L. (2018). Above a swamp: a theory of high-quality scientific production. *Research Policy*, 47 (5): 827-839.
- Okunade, A.A. (1992). Functional forms and habit effects in the U.S. demand for coffee. *Applied Economics* 24(11): 1203-1212.

Pesaran, H. (2003). Introducing a replication section. *Journal of Applied Econometrics*, 18(1): 111.