Population Growth and GDP Per Capita Growth: Identifying the Causal Variable in 30 African Countries

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Abstract
Within a wider framework of institutional factors of economic growth and the relationship between population growth and GDP growth, this article focuses on the population growth and GDP growth per capita for 30 countries in Africa between 1960 and 2020. We provide a comparative analysis of approaches to methodology and results obtained in the impact of population growth on GDP/pc growth discourse. By performing the Bootstrapped Panel-Granger Causality test, the estimation results show that half of the countries showed no causality and other half of countries showed different levels of significant causality. The most seen causality is the unidirectional causality from GDP growth per capita to population growth. In addition, unidirectional causality is observed from population growth to GDP growth per capita and bidirectional causality. Overall, the results add more evidence into the research of endogenous population growth theory, which implies that there is country-specific environment which determines the causality between these two variables.

Keywords: population growth; GDP growth per capita; Bootstrapped Panel-Granger Causality test; endogenous theory of population growth

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1. Introduction

Macroeconomists focus on the beginning of the endogenous growth models on variables which have direct influence on the product such as capital, interest rate, or saving rate. Other variables included in the models were considered exogenous. Continuous research tried to endogenize these variables and found theoretical formulas for them, for example, how technology growth depends on growth of product and vice versa. Theoretical approaches give us a baseline on how we should deduct empirical research. Empirical researchers should focus on the reflection of this theoretical formula in the real word and on whether there is a causality relationship between these variables.

Niehans (1963) as the first-introduced growth model with endogenous population growth. This author uses the Solow – Swan model where he endogenizes the population growth. He comes to conclusion that population growth influences future capital, and it depends not only on the

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capital in the present time, but also on starting point of the economy and initial level of income. Nerlove & Raut (1997) created a growth model with a three-factor production function and determines that the important factor of population growth is an minimal wage, which is important part of the population growth formula. Heintz & Folbre (2022) presented a model in which they showed how fertility influences economic growth in the future. They found that low fertility leads to a decrease of the country economy and probably even a decrease of the world economy.

Kelley & Schmidt (1994) summarized the knowledge on population growth and its influence on the economy. This article divides this influence on the economic growth, household savings, household decision making, level, and composition of government expenditure. An important feature of this article is the demand to include more microeconomics foundation into macroeconomic models. Population growth is one of the factors, which also creates demand for technology (mainly in the agriculture sector). An example of this is shown by Lanz et al. (2017). Population is an important factor for the pension system in the country, mainly in western economics. Many countries use the pay as you go system, which depends on the high population growth (Dimitrov & Hadad, 2022). Tabata (2015) focuses on how the change in population growth affects capital accumulation and therefore the level of output which the economy can produce. In this sense, the labor force loss during the Covid pandemics has been confirmed to contribute to weak economic growth in the post-Covid period (Bednar & Kaderabkova, 2022).

The purpose of this article is to contribute to the endogenous population growth discourse by testing the causal relationship between population growth and GDP growth per capita. As shown in Section 2, empirical research differs in the outcome. For this reason, we use the Bootstrapped Panel-Granger Causality test (BPGC) for the data from African countries to add more evidence to this field of research. Section 3 more closely the methodology and Section 4 shows the result of the empirical analysis. Section 5 concludes this article.

2. Literature review

Some empirical studies examine the relationship between population growth and GDP growth. Researchers mainly focused on two approaches. First, they studied the causality between population growth and the GDP growth per capita. Second, they used cross-sectional analysis with control variables. An example of such research is shown in ***Table 1***.

Table 1. Previous empirical research

Author(s)	Time	Countries	Methodology	Results
Thornton (2001)	1921-1994	Argentina, Brazil, Chile, Colombia, Mexico, Peru, Venezuela	Cointegration analysis and Granger causality	No causality between population growth and GDP growth per capita
Munir et al. (2009)	1961 – 2003	Thailand	Cointegration analysis and Granger causality	Population growth positively influences GDP growth per capita

Furuoka & Munir (2011)	1960 - 2007	Singapore	Cointegration analysis and Granger causality	Positive both way causality
Furuoka (2013)	1960 - 2007	Indonesia	Cointegration analysis and Granger causality	Population growth positively influences GDP growth per capita
Darrat & Al-Yousif (1999)	1948 - 1996	20 developing countries	Granger causality and Error Correction model	14 countries: Population growth positively influences GDP growth per capita 2 countries: Population growth negatively influences GDP growth per capita 4 countries: Positive bidirectional effect
Singha & Jaman (2013)	1960 - 2010	India	Granger causality and Error Correction model	No causality
Garza-Rodriguez et al. (2016)	1960 – 2014	Mexico	Vector Correction model	Positive effect in both ways
Afzal (2009)	1981 - 2015	Pakistan	OLS	The negative effect of population growth on GDP growth per capita
Koduru & Tatavarthi (2021)	1985 - 2015	India	OLS	The positive effect of population growth on GDP growth per capita
Dao (2013)	1990 – 2008	45 African Countries	Cross-section regression analysis	The negative influence of population growth on GDP growth per capita
Chang et al. (2017)	1870 – 2013	21 countries	Bootstrapped Panel-Granger Causality test	5 countries: GDP growth per capita has an effect on population growth 4 countries: Effect of population growth on GDP growth per capita 2 countries: Bidirectional causality 11 countries: No causality

Note: Own research

It is clear from the shown research that the results depend on the methodology used, time and countries. These results vary among the studies. The closest research to the aim of this article is from Dao (2013), who discover the negative influence of population growth on GDP growth per capita. Next, the author specifies that population growth can be slowed by government in a area where there is the high rate of urbanization. The interaction between urbanization and population growth has a negative influence on GDP growth per capita. However, some countries with a high fertility rate and a high urban population growth rate have a higher GDP growth per capita. In conclusion, the relationship between population growth and GDP growth per capita is not the same for whole interval, but for some interval the relationship is negative and from some level is positive. This also depends on combination of variables and their level.

Another research related to this article is from Chang et al. (2017). They used the Bootstrapped Panel-Granger causality (BPGC) test, which is used in this article. In their approach, they use variables population growth and standard of the living growth, which they presented as real GDP growth per capita. By this method, they find different interaction between these two variables. They found a one-way Granger causality effect from standard of living growth to population growth in Canada, Norway, and Switzerland. Germany and Japan have a negative effect on the same causality. The second positive Granger causality effect that runs from population growth to standard of living growth is present in France. Finland, Sweden, and Portugal have shown a negative effect of this causality. The bidirectional effect is found in Italy and Austria. Other countries did not show an effect.

3. Methodology

This article applies BPGC developed by Kónya (2006). This model uses unit root test and cointegration test, which are robust. Thus, there is no requirement for stationary conditions. First, the model needs to determine a system of equations for zero restriction according to Wald principle. Each country will have specific value and specific bootstrapped critical value and thus joint test hypotheses is not needed. The system of equation is established by Seemingly Unrelated Regressions (SUR). The system of equations is composed of two sets of, specifically:

$$GDP_{1,t} = \alpha_{1,1} + \sum_{i=1}^{ly_1} \beta_{1,1,i} GDP_{1,t-i} + \sum_{i=1}^{lx_1} \delta_{1,1,i} POP_{1,t-i} + \varepsilon_{1,1,t}$$

$$GDP_{2,t} = \alpha_{1,2} + \sum_{i=1}^{ly_1} \beta_{1,2,i} GDP_{2,t-i} + \sum_{i=1}^{lx_1} \delta_{1,2,i} POP_{2,t-i} + \varepsilon_{1,2,t} \quad (1)$$

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$$GDP_{N,t} = \alpha_{1,N} + \sum_{i=1}^{ly_1} \beta_{1,N,i} GDP_{N,t-i} + \sum_{i=1}^{lx_1} \delta_{1,N,i} POP_{N,t-i} + \varepsilon_{1,N,t}$$

and

$$POP_{1,t} = \alpha_{2,1} + \sum_{i=1}^{ly_2} \beta_{2,1,i} GDP_{1,t-i} + \sum_{i=1}^{lx_2} \delta_{2,1,i} POP_{1,t-i} + \varepsilon_{2,1,t}$$

$$POP_{2,t} = \alpha_{2,2} + \sum_{i=1}^{ly_2} \beta_{2,2,i} GDP_{2,t-i} + \sum_{i=1}^{lx_2} \delta_{2,2,i} POP_{2,t-i} + \varepsilon_{2,2,t} \quad (2)$$

.
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$$POP_{N,t} = \alpha_{2,N} + \sum_{i=1}^{ly_2} \beta_{2,N,i} GDP_{N,t-i} + \sum_{i=1}^{lx_2} \delta_{2,N,i} POP_{N,t-i} + \varepsilon_{2,N,t}$$

where GDP refers to the GDP growth per capita, POP to the population growth, N to the number of countries, t to the time periods and l is the lag length. Values of variables are different in each equation and these values can be cross-sectional correlated in error terms. Thus, for testing the Granger causality, there are four possible results:

1. Unidirectional causality from POP to GDP, thus not all $\delta_{1,i}$ are zero and all $\beta_{2,i}$ are zero
2. Unidirectional causality from GDP to POP, thus all $\delta_{1,i}$ are zero and not all $\beta_{2,i}$ are zero
3. Bidirectional causality between GDP and POP thus not all $\delta_{1,i}$ and not all $\beta_{2,i}$ are zero
4. No causality between GDP and POP thus all $\delta_{1,i}$ and $\beta_{2,i}$ are zero

The proposed system of equations is shaped by the lag length. For robustness test which appears in the result we set optimal lag length. Kónya (2006) proposed that maximal lags can differ across variables, but they must have same value across equations. In this proposed regression system, it is considered one to eight lags. Kónya (2006) recommends using Schwarz Bayesian Criterion (SBC) and Akaike Information Criterion (AIC) for determination of optimal lag length. The results are presented in ***Table 2***.

Table 2. Optimal lag length result

LAG GDP	SBC	AIC	LAG POP	SBC	AIC
1	**-187.01**	**-190.18**	1	-468.44	-471.82
2	-173.86	-184.53	2	**-490.03**	-501.28
3	-152.08	-174.66	3	-481.96	**-505.60**
4	-121.18	-160.25	4	-458.35	-498.88
5	-80.73	-140.95	5	-413.67	-475.58
6	-30.71	-116.90	6	-359.14	-446.95
7	28.63	-88.48	7	-297.62	-415.82
8	100.98	-52.12	8	-231.42	-384.52

Note: Bold number is the lowest number in the column. The optimal lag length is tested on the full sample of 30 African countries in time period 1960 – 2020. Own construction.

Next, we need to test cross-sectional dependence and slope homogeneity. Results of tests are shown in the ***Table 3***. Null hypothesis of all tests is rejected. Thus, there is cross-sectional dependence and SUR is valid method to use and there is unique heterogeneity. Links between population growth and GDP growth per capita differs for each country.

Table 3. Test statistics result

Test	Statistic	Probability
Breusch – Pagan LM test	2309.167	0.0000
Pesaran scaled LM	8.053511	0.0000
Pesaran CD	9.578419	0.0000

Pesaran, Yamaguta slope test	4.856	0.0000
Adjusted Pesaran, Yamaguta slope test	4.980	0.0000

Data is collected from the World Bank database. Countries which have data from the year 1960 are used. The rule of thumb which we applied was to use only periods and countries which have mostly all data points available. There were a few cases, in which the value was missing between periods, so we decided to replace these points by the middle value of the year before and after. If one value was missing only at the end or beginning of the dataset period, it was replaced by the mean of the previous two years or mean of two following years respectively. Source of the code for BGCP in this article was programmed in Menyah et al. (2014). For the purpose of this article, we did small adjustments.

4. Results

Table 4 presents the results with population growth as a causal variable. There is a causal relationship in six countries, three countries on a 5% significance level and three countries on a 10% significance level. For the other 24 countries there is no causality.

Table 4. BPGC estimations for population growth

N = 30
T = 60
lag = 2
10 000 replications
Population growth does not cause GDP growth

Country	Wald statistics	Bootstrap critical value		
		1%	5%	10%
Algeria	1.181	32.187	20.796	15.128
Benin	19.148**	28.437	17.832	13.431
Botswana	3.239	30.403	19.583	14.835
Burkina Faso	3.686	27.701	17.337	13.073
Burundi	13.980	29.976	18.729	14.034
Cameroon	8.656	31.946	21.351	16.200
Central African Republic	3.606	26.694	17.104	12.904
Congo, Dem.	15.909**	25.481	15.776	11.983
Congo, Rep.	13.870*	28.521	17.160	13.145
Core d Ivore	2.196	30.523	17.905	13.239
Egypt	2.453	33.020	20.041	15.032
Gabon	0.974	29.897	17.833	13.166
Ghana	3.904	35.203	22.349	16.496
Chad	3.663	35.333	21.394	15.686
Kenya	5.776	36.887	20.778	15.465
Lesotho	9.105	30.433	16.884	12.128
Madagascar	7.361	37.389	21.300	15.317

Malawi	7.972	39.980	22.679	16.358
Mauritania	11.082	42.712	23.142	16.817
Niger	0.593	39.380	19.889	14.032
Nigeria	16.174*	31.969	19.046	14.429
Rwanda	0.175	27.585	17.622	13.178
Senegal	0.870	28.521	16.859	12.547
Seychelles	5.181	43.674	29.304	22.900
Sierra Leone	15.999*	27.502	16.555	12.535
South Africa	1.578	29.537	17.714	12.759
Sudan	0.212	31.670	19.173	14.472
Togo	2.371	28.436	17.746	13.072
Zambia	19.131**	30.838	19.026	14.617
Zimbabwe	1.440	31.918	19.390	14.428

Note: *** Wald statistics > Bootstrap critical value at 1% level, ** Wald statistics > Bootstrap critical value at 5% level, * Wald statistics > Bootstrap critical value at 10% level. Own construction.

Table 5 presents the results with GDP growth per capita as a causal variable. There is a causal relationship in twelve countries, five countries on 1% significance level, four countries on 5% significance level, and three countries on 10% significance level. For the other 18 countries there is no causality.

For all countries there is only unidirectional causality except for the Democratic Republic of the Congo and the Republic of Congo, where the causality is bidirectional. This analysis shows that in Africa there is no causal effect for 14 countries. The highest levels of significance and number of the countries are observed when GDP growth per capita is a causal variable. This suggests that GDP growth per capita is probably a driving factor for population growth in Africa, rather than vice versa.

Table 5. BPGC estimations for GDP growth per capita

N = 30
T = 60
lag = 1
10 000 replications
GDP growth does not cause population growth

Country	**Wald statistics**	**Bootstrap critical value**		
		1%	**5%**	**10%**
Algeria	2.577	40.977	24.000	17.852
Benin	7.522	77.487	50.915	40.344
Botswana	0.073	6.426	3.511	2.398
Burkina Faso	15.638***	10.938	6.166	4.417
Burundi	0.009	5.105	2.932	2.063
Cameroon	13.323***	7.738	4.259	2.936
Central African Republic	0.559	9.907	5.295	3.650
Congo, Dem.	15.142**	17.143	9.421	6.538
Congo, Rep.	4.227*	11.882	5.885	3.943

Core d Ivore	22.584***	10.776	7.129	5.788
Egypt	51.846***	8.434	4.450	3.066
Gabon	19.228***	8.242	4.952	3.692
Ghana	11.527	55.457	33.991	21.841
Chad	5.745*	12.211	6.732	4.580
Kenya	19.511**	27.186	15.525	11.144
Lesotho	8.043	26.108	14.594	10.178
Madagascar	0.003	41.450	16.519	9.876
Malawi	0.034	13.881	7.450	5.171
Mauritania	9.288	56.756	34.641	25.708
Niger	0.639	24.281	15.307	11.620
Nigeria	0.906	22.787	11.066	7.487
Rwanda	0.002	4.544	2.591	1.863
Senegal	11.332*	21.882	12.411	8.827
Seychelles	17.449**	30.982	17.340	12.133
Sierra Leone	16.032	61.126	36.775	26.656
South Africa	7.397**	12.434	6.544	4.458
Sudan	2.559	10.724	5.566	3.560
Togo	0.054	5.484	3.246	2.387
Zambia	1.278	21.333	11.840	8.192
Zimbabwe	3.625	46.619	29.410	21.812

Note: *** Wald statistics > Bootstrap critical value at 1% level, ** Wald statistics > Bootstrap critical value at 5% level, * Wald statistics > Bootstrap critical value at 10% level. Own construction.

5. Conclusion

The present study investigates the causal relationship between population growth and GDP growth per capita for 30 countries in Africa between the year 1960 and 2020. Results can be divided into four categories by frequency and significance level. First, for most countries there is no causal relationship. Second, GDP growth per capita is a causal variable. This is the second most observed result. Third, population growth is a causal variable. Forth, there is a bidirectional relationship. These results add more evidence to the research of theory of endogenous population growth. The countries have different causal relationships. It would be beneficial for future research to investigate the country-specific environment and look for the explanation of why we see different causal relationship. This article can serve as a tool for the distribution of countries into clusters for future research.

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