Exploring the indirect effect of the population growth on income growth through investment: simple mediation analysis and its limitations

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I: Introduction and Literature Review

Population problems persist and are diverse among countries. The substantially high population growth is a common problem in many developing countries while some developed countries are concerned about the aging population. Many previous studies suggest that a high population is associated with low economic growth. However, in recent decades, the negative relationship seems contradictory to the fact. In some developing countries, both the population and per capita growth have slowed down from the 60s to the 90s (Easterly, 2002).

It is hard to develop a causality between the population growth and economic growth because there are too many potential factors lying in the relationship, which are hard to study quantitatively.

Previous studies suggested many possible ways that population growth can economic growth. For example, some studies suggest that lower fertility and population aging are positively associated with per capita income through the accumulation of human capital. Because lower fertility is associated with higher expenditure on human capital per child, which will in turn benefit the income growth (Lee and Mason, 2009). However, some suggest that excessively high population growth may be problematic because existing capital will be diluted, which in turn affects productivity and income (Weil, 2016).

A few growth models consider that population or fertility would affect investments in physical capital. Some studies suggested that people may shift from savings in the form of children to other forms like physical capital (Barro, 1991). If considering fertility as a substitute for the investment in physical capital, this negative and indirect effect may reinforce the adverse effect of high fertility on economic growth (Barro, 1999).

However, there is little study about the direction and magnitude of the indirect effect of population growth on economic growth by affecting investments. This topic can be important because when designing population policies, it is important to know how the mechanism that change in the population would affect the economy, to better evaluate the costs and benefits of policies and choose the most suitable policy for economies. Thus, this paper will try to explore the indirect effect of population growth through investments on income growth using simple mediation analysis. Limitations of the methodology will also be discussed for further exploration.

II: Review of Classic Models of Growth

Classic models for economic growth include the Harrod-Domar model and the Solow model. They both study the effect of investment in capital and population growth on economic growth and they both consider the population growth as exogenous to the investment in physical capital.
In the simplest version of the Harrod-Domar model, all savings are assumed to be invested in capital, so the gross investment ratio is equivalent to the saving ratio (Todaro and Smith, 2015).

Figure 1: Harrod-Domar Model with Population Growth

$$1 + g_{pc} = \frac{\frac{s}{c} + 1}{1 + n}$$

g_{pc}: $per\ capita\ growth$;

s: $gross\ saving\ ratio$;

c: $capital - output\ ratio$;

n: $population\ growth\ rate$;

As shown in Figure 1, the per capita growth is positively related to the saving ratio and negatively related to the capital-output ratio and population growth.
However, this simple version of the Harrod-Domar model has simplified some complex factors like labor productivity and technology, while the Solow model relaxes some assumptions by considering these factors (Weil, 2016).

Figure 2: Solow Model with Population Growth

$$k(t+1) - k(t) = \gamma f(k) - (n + \delta)k, \qquad f(k) = Ak^b$$

Steady State (k*):

$$k^* = \left(\frac{\gamma A}{(n + \delta)}\right)^{1/(1-b)}$$

$k(t)$: $capitals\ per\ worker\ at\ time\ t$;

γ: $investment\ ratio\ to\ GDP$;

n: $popoulation\ growth$;

δ: $depreciation\ rate\ of\ capitals$;

$f(k)$: $output\ at\ k$;

A: $Level\ of\ technology$.

In the Solow model, shown in Figure 2, economies will converge to the steady state, at which the investment ratio of output is equal to the depreciation of capital, and the change in the capital should be zero at the steady state. Higher population growth would dilute capital and lead to lower income at the steady state.

Now, if we assume the population growth is endogenous to the investment ratio and write investment as a function of population growth, the effect of population on growth in both models can be uncertain. If the high population is a substitute for other investments, the function of the investment ratio should be decreasing in population, and the negative effect of population growth was underestimated in the models above.

Intuitively, this indirect effect on the population may change with income levels. As income increases to the level at which people do not have to choose between more children and other investments, this negative indirect impact may disappear. The following sections will explore these questions using a simple empirical approach as well as discuss their limitations.

III: Methodology

This paper uses the basic mediation analysis model with one mediator (Hayes, 2009). As shown in Figure 3, M is the mediator between the independent variable (X) and dependent variable (Y), c is the total effect, a*b can be interpreted as the indirect effect of X on Y through M, and c' is the direct effect or effects through other mediators. For a valid mediation effect, coefficients a, b, and c need to be statistically significant. If c' is also significant, the effect of X on Y is partially mediated otherwise fully mediated.

Figure 3: Model with One Mediator

X: Independent Variable.

Y: Dependent Variable.

M: Mediator.

$$Y = i_1 + cX + u_1$$
$$M = i_2 + aX + u_2$$
$$Y = i_3 + c'X + bM + u_3$$

In this study, the investment ratio (% of GDP) is the mediator, and specifications are shown below:

$$\ln(GDP\ per\ capita)_{i,t} = \alpha_0 + \alpha_1 \ln(Pop)_{i,t} + \alpha_2 Enrolment\ ratio_{i,t} + \alpha_3 Unemployment_{i,t} + \alpha_4 Inflation_{i,t} + \alpha_5 Income\ Share_{i,t} + \alpha_6 Government\ expenditure_{i,t} + X_i + Y_t + u_{i,t} \quad (1)$$

$$ln(Investment\ ratio)_{i,t} = \beta_0 + \beta_1 \ln(Pop)_{i,t} + \beta_2 Enrolment\ ratio + \beta_3 Unemployment\ rate + \beta_4 Inflation + \beta_5 Income\ share + \beta_6 Government\ expenditure + X_i + Y_t + \varepsilon_{i,t} \quad (2)$$

$$\ln(GDP\ per\ capita)_{i,t} = \gamma_0 + \gamma_1 \ln(Pop)_{i,t} + \gamma_2 \ln(Investment\ ratio)_{i,t} + \gamma_3 Enrolment\ ratio_{i,t} + \gamma_4 Unemployment\ rate_{i,t} + \gamma_5 Inflation_{i,t} + \gamma_6 Income\ Share_{i,t} + \gamma_7 Government\ expenditure_{i,t} + X_i + Y_t + \theta_{i,t} \quad (3)$$

Here, $Pop_{i,t}$ is the population of country i in year t. $investment\ ratio_{i,t}$ is the sum of values of gross fixed capital formation, change in inventories, and net gain of valuables in current local currency. $GDP\ per\ capita_{i,t}$ is calculated in current US dollar and adjusted by PPP. X_i and Y_t capture the fixed effects for countries and years respectively.

Reference to previous studies about investments and income growth (Blomström, Lipsey and Zejan, 1996), some control variables are included: $Enrolment\ ratio_{i,t}$ (gross enrolment ratio of population for secondary education), $Unemployment\ rate_{i,t}$, $Inflation_{i,t}$ (percentage

change of average consumer price), $Income\ Share_{i,t}$ (income share held by poorest 20%), and $Government\ expenditure_{i,t}$.

Moreover, considering the effect might vary across different income levels, the same specifications are run again only for observations with GDP per capita less than 9000 dollars for comparison.

Data

The sample includes 193 countries over the period from 2002 to 2016. Datasets for population, investment ratio, unemployment rate, inflation, and government expenditure are collected from IMF World Economic Outlook. Datasets for GDP per capita and income share are from The World Bank (World Development Indicator). The data for gross enrolment ratio is collected from UNESCO Institute for Statistics.

Figure 4: Summery of Data

Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
ln(GDP per capita)	2464	9.241	1.207	6.577	11.995
ln(Pop)	2733	15.621	2.063	9.105	21.047
ln(Investment ratio)	2456	3.122	.373	.338	4.29
Enrolment ratio	1011	68.694	25.783	4.043	100
Unemployment rate	1628	8.929	5.795	.488	37.25
Inflation	2733	5.523	6.708	-12.563	98.219
Income share	1037	6.744	2.014	1.7	10.9
Government expenditure	2733	31.094	12.914	0	97.122
Population	2733	36298580	1.357e+08	9000	1.383e+09
Investment ratio	2456	24.197	8.674	1.402	73.002
GDP per capita	2464	19243.615	21124.402	718.333	161938.75

IV: Results

Results for the whole sample are shown in Figure 5, all the key coefficients for the validity of the mediation effect are significant. Here the total effect is -0.400, which suggests a 1% increase in population is associated with a 4.00% decrease in GDP per capita. The indirect effect is approximately 0.116*0.791=0.09176, which means population growth positively affects GDP per capita by positively affecting the investment ratio.

However, this indirect effect is relatively small, referring to the coefficient of the population in the third regression, the direct effect, or effects through other channels of the population on per capita GDP is negative, larger, and significant. Thus, the total effect is still negative.

Interestingly, as shown in Figure 6, the indirect effect becomes negative when the sample only includes observations with GDP per capita of fewer than 9000 dollars. This suggests when income is low, a higher population is likely to crowd out other capital investments. However, the coefficient of the population in the regression (2) becomes insignificant, which means the interpretation needs more caution.

Figure 5: Result for Whole Sample

VARIABLES	(1) lnGDP_capita	(2) lnInvestment	(3) lnGDP_capita
lnPop	-0.400*	0.791**	-0.492**
	(0.228)	(0.330)	(0.216)
lnInvestment			0.116**
			(0.0453)
Enrolment_all	0.00491***	0.00417*	0.00442**
	(0.00179)	(0.00246)	(0.00184)
Unemployment	-0.0158***	-0.0362***	-0.0116***
	(0.00213)	(0.00449)	(0.00242)
Inflation	-0.000499	-0.00121	-0.000359
	(0.000827)	(0.00119)	(0.000799)
Income_share	0.0230	-0.00346	0.0234
	(0.0150)	(0.0176)	(0.0147)
Government_expenditure	-0.00231	-0.00312	-0.00194
	(0.00156)	(0.00295)	(0.00155)
(constant and dummies are hided for simplicity)			
Observations	478	479	478
R-squared	0.767	0.641	0.780

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 6: Result for the Subsample

VARIABLES	(1) lnGDP_capita	(2) lnInvestment	(3) lnGDP_capita
lnPop	-0.988***	-1.033	-0.834***
	(0.279)	(0.790)	(0.199)
lnInvestment			0.149***
			(0.0149)
Enrolment_all	-0.00317*	0.00522	-0.00395**
	(0.00175)	(0.00681)	(0.00135)
Unemployment	-0.0180***	-0.0557***	-0.00962**
	(0.00449)	(0.0124)	(0.00381)
Inflation	0.00285	0.00804	0.00165*
	(0.00188)	(0.00880)	(0.000926)
Income_share	-0.0661***	-0.0640**	-0.0565***
	(0.00787)	(0.0253)	(0.00725)
Government_expenditure	0.00128	0.0236	-0.00225
	(0.00396)	(0.0169)	(0.00268)
(constant and dummies are hided for simplicity)			
Observations	64	64	64
R-squared	0.942	0.651	0.958

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

V: Discussion and Limitation

Because of the methodology, the limitations of the study are also obvious. First, most mediation analyses used cross-sectional data, this simple model may not be suitable for panel data analysis. More complex models like the autoregressive model can be considered further (MacKinnon, Fairchild, and Fritz, 2007).

Potential bias caused by both the nature of cross-country sampling and mediation analysis is also worth mentioning. Most studies about mediation effects control the same variables for different steps of regressions, but some variables may only be valid control variables only for some steps. Inappropriate control variables may affect the significance and consistency of key coefficients. Further tests for other potential controls like the debt-output ratio may be needed.

Some may be concerned about the problems of endogeneity for regression (1) because compared with (3), obviously (1) omit the mediator. To study this problem, substituting (2) into (3) and transforming it into a form like (1). Looking at the result (4), its consistency depends on whether $\gamma_2\varepsilon_{i,t}$ and $\theta_{i,t}$ are uncorrelated with independent variables. Whether this strong assumption can be satisfied is questioned. Further studies can try to introduce instrumental variables to alleviate the problem.

$$\begin{aligned}\ln(GDP\ per\ capita)_{i,t} &= \gamma_0 + \gamma_1\ln(Pop)_{i,t} + \gamma_2\,(\beta_0 + \beta_1\ln(Pop)_{i,t} + \beta_{control}control\ variables \\ &+ \varepsilon_{i,t}\ ) + \gamma_{control}control\ variables + \theta_{i,t} \\ &= \gamma_0 + \gamma_2\beta_0 + (\gamma_1 + \gamma_2\beta_1)\ln(Pop)_{i,t} + (\gamma_2\beta_{control} \\ &+ \gamma_{control})control\ variables + \gamma_2\varepsilon_{i,t}\ + \theta_{i,t}\end{aligned} \quad (4)$$

VI: Conclusion

To conclude, the model and empirical evidence suggest that the population growth might have a positive indirect effect on income growth by positively affecting the investment ratios, but this effect might reverse if income is too low. Because of limitations of data structure and methodology, this result needs further testing, but it can give some insights into the possible mechanism of population policies in countries with different income levels.

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