Neoclassical growth in the last half century

An empirical study

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Abstract

The neoclassic growth model is well studied both theoreically and empirically. The idea that the initial level of GDP has an effect on growth in the following period is well documented. At first glance the effect of initial GDP on growth is weak an not statistically significant. When controlling for human capital and other external factors one finds that in the period 1960-2000 there has been a clear and negative correlation between the two.

This paper builds directly on an empirical study done by Robert J. Barro in 1991 on the neoclassic model, expanding it both in time and variables. The findings match his very closely.

1 Introduction

Does the core argument of the neoclassic growth model hold in an empirical analysis? In the article "Economic Growth in a Cross Section of Countries" by Robert J. Barro from 1991, he does an empirical analysis of several countries' growth in the years 1960-85. He finds the theory holds when controlling for human capital.

In this paper I will first go through some of the established theory within neoclassic growth, including some of the critique against the model. Then I will go through how Barro (1991) has tested the model and what part of his analysis I will focus on. Thereafter I will try to outline the main differences in my analysis and Barro's. Going through the model, first outlining the simple baseline and thereafter expanding it, I will provide logical and theoretical support for the variables I use, before rounding it off with an evaluation of the neoclassic growth model and trying to answer the question here posed.

1.1 Established theory: Solow Model

Much of the literature on economic growth is based on the neo-classical growth theory. This theory builds on the concept of convergence. It states that capital has diminishing returns to scale and therefore creates a relative greater return per unit in countries with little capital per capita than in the ones with a lot . The expectation of this theory will then be that the poor countries should grow faster than the rich ones. (Barro & Sala-i Martin 2003)

One such model is the Solow-Swan model, or just Solow model, that long has been the main model within neoclassical growth theory. It explains growth from a steady state perspective (Weil 2005). It is based on the relationship of GDP[1] per capita (y) and level of capital per capita (k). When the model is in steady state, the capital depreciation equals the investments $[(n+d)k = sy]$, n is population growth rate, d is the capital depreciation rate and s is the investment rate. Such a situation is without growth, reflected in no long term growth in the model. In the figure above, the steady state is at point A.

This model predicts convergence of GDP over time, meaning that once an initially poor country and an initially rich country come to the point of steady state they should have the same GDP for a given rate of investment. It was first published in

[1] Gross Domestic Product

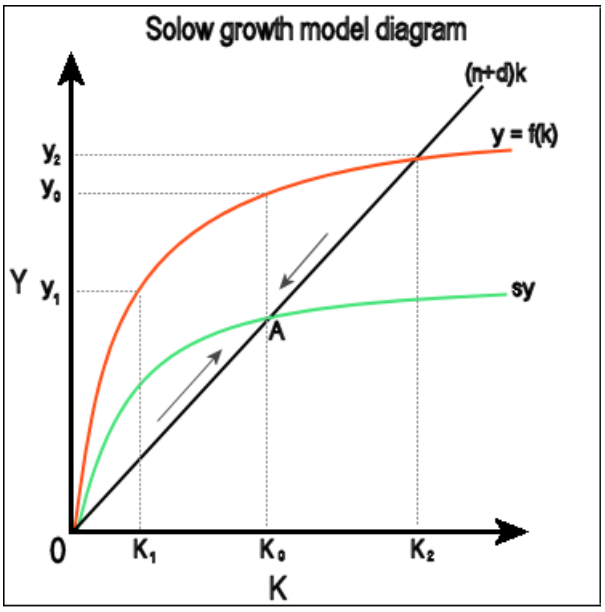


Figure 1: Graphic representation of the Solow model (Wikipedia 2007)

the fifties and has for many years been the baseline for research in economic growth. According to this model growth in GDP should, ceteris paribus, be negatively correlated with the size of GDP (Barro 1991). The reason being that the further away from the steady state (point A), the more every unit of capital will help, creating a higher degree of growth given the same level of investment.

The neoclassical model, fronted by Solow, has some major weaknesses. In the eighties researchers tried to go beyond what Solow and his exogenous model of economic growth could explain. They tried to endogenize growth and make models that were would incorporate technological progress into the growth models. Researchers like Prescott (1998) and de la Fuente & Doménech (2001) have called out for a better model.

> These findings reinforce recent calls [...] for better models of technical progress as a key ingredient for understanding international income dynamics [...]. (de la Fuente & Doménech 2001)

In spite of the critiques, I will be using the traditional neoclassic model for my study, as others have done before me.

1.2 Testing the theory

Many have tested the neoclassical theory with its weaknesses in mind. The most interesting finding in my opinion, and the one I mainly will be testing is that:

> [...] the simple correlation between per capita growth [...] and the initial [...] level of per capita GDP is close to zero, the correlation becomes substantially negative if measures of initial human capital [...] are held constant. (Barro 1991)

Robert J. Barro (1991) tried through his analysis to find if the neoclassic theory of growth could explain the economic growth in the mid to late twentieth century, doing analysis on data from 1960-85. As mentioned above, he found that the correlation between size of GDP and the growth rate is negative and significant as long as one controls for level of human capital and a few other factors.

1.3 Importance of this paper

Compared to the previously mentioned research in this field, I have mostly the same approach. Barro (1991) has in his article gone farther than I have, testing fertility rates as well as growth as the dependent variable, but due to space restraints I have focused on improving on his growth analysis.

This paper is mainly written to extend the previous research in time, making the analysis over 40 years, rather than 25. In addition I have tried to use a series of variables that I believe are important to control for in such an analysis. I end up with a model of 12 independent variables that has quite a good model fit[2] and is supported by the current theory.

2 Methodology

The purpose of this paper is to analyse neoclassical growth theories in an empirical framework. It is only natural that the dependent variable is growth. I have used growth in Real GDP from 1960 to 2000. I have looked at 73 countries which have data in all the variables, Barro (1991) used 98, but some of the countries have ceased to exist since 1985 and some did not have all the variables available. See appendix for complete list of countries. I chose to use data from the Penn World Table (Heston, et al. 2006) as the source for economic data as it is a good and widely reckognized source of dependable data. They also have the advantage of being available for the years I am trying to analyze.

[2] $R^2 = 0,814$

Like Barro, I too will control for human capital. When considering the wide variety of measures in such a construct as human capital I chose to use somewhat equal measures of human capital as was done by Barro (1991). I have chosen to use three variables as the human capital measure. Percentage of population above age 15 with completed primary school[3], percentage of population above age 15 with completed secondary school[4] and percentage of population above age 15 with completed higher schooling[5]. For these I use data gathered by Barro & Lee (1986). They are the most comprehensive data I have found on this topic from 1960.

The reason for not using the same education data used by Barro (1991) in this paper is that I believe that data on completed education in 1960 is a better measure of initial level of human capital than enrollment in 1960. Barro tries to solve this by adding enrollment in 1950, whereas my data have already controlled for this problem, and do not need to add an earlier year.

Using simple OLS-regression I will test if the findings of Barro (1991) still hold and if the analysis can be improved, using other variables.

3 Findings

My initial model is pretty straight forward. It is simple, clear and has four independent variables. The dependent variable is GR19602000[6]. The independent are RGDP1960[7], PRIC15, SECC15 and HIC15. Saying that these are completely independent from both level of GDP and that there is no causality from high growth to level of schooling may be problematic, but that is not a debate for this paper. I will simply assume that they are in fact independent.

$$\text{GR19602000} = \beta_0 + \beta_1 \text{RGDP1960} + \beta_2 \text{PRIC15} + \beta_3 \text{SECC15} + \beta_4 \text{HIC15} + \varepsilon \quad (1)$$

Although none of the estimates[8] are significantly different from zero, the core argument of Barro (1991) seems to hold. There seems to be a negative correlation between GDP and growth rate. As I will show when I start controlling for descriptive factors this correlation becomes stronger and significant.

[3] PRIC15
[4] SECC15
[5] HIC15
[6] GR19602000 is the total growth in Real GDP per capita from 1960 to 2000
[7] RGDP1960 is the level of real GDP per capita in 1960
[8] See appendix A

3.1 Expanding the model

The model as it stands does not seem to be a very good one. It is faced with two options, either be discarded to the advantage of a different theory or be expanded. I choose to try to improve the model by controlling for some of the factors that may affect growth in the individual countries, trying to put the interesting variable on a level field.

3.1.1 Population growth

Population growth is a variable that in the neoclassic theory is well incorporated. When the growth rate of the population is high, the model says, growth in GDP per capita is low (Weil 2005). In (2) we incorporate this through POPGR19602000[9].

$$\begin{aligned} \text{GR19602000} = \beta_0 + \beta_1 \text{RGDP1960} + \beta_2 \text{PRIC15} + \beta_3 \text{SECC15} \\ + \beta_4 \text{HIC15} + \beta_5 \text{POPGR19602000} + \varepsilon \end{aligned} \tag{2}$$

Adding the population growth to the model has both a theoretical sound basis, and strengthens the model for the given data. Not only does population growth affect economic growth with a coefficient significantly different from zero, it also strengthens the effect of GDP to growth making *it* significantly different from zero.

The fact that this model takes population growth as an independent variable, goes in strict contradiction to i.e. a Malthusian model of population growth (Barro & Sala-i Martin 2003).

3.1.2 Non-linearity and geography

Looking at the data, it seems the correlation between growth and GDP may not be linear, so like Barro (1991) in (3) I have added a squared GDP 1960[10]. This will control for any nonlinearity in the data.

$$\text{GR19602000} = \beta_0 + [\ldots] + \beta_6 \text{GDP60SQ} + \varepsilon \tag{3}$$

As well as controlling for nonlinearity I have to control for geography. (4) I have added some regional dummies. Being in South East Asia seems to be strongly positively correlated with growth, whereas being in Latin America has little effect

[9] POPGR19602000 is the population growth from 19602000 in percent

[10] GDP60SQ

and is not significantly different from zero.

$$\text{GR19602000} = \beta_0 + [\ldots] + \beta_7 \text{South East Asia} + \beta_8 \text{Latin America} + \varepsilon \quad (4)$$

Both of these expansions have both strengthened the model with an increased R^2, as well as given some interesting results. In (3) there seems to be a severe increase in the RGDP1960 coefficient from (2). Possibly because of non-linearity in the data being removed with the squared variable.

When controlling for geography, the increase in the RGDP1960 coefficient seems to have diminished. This can be attributed to the fact that once non-linearity is taken care of, the strongest variation caused by the RGDP1960 variable are in fact caused by other variables not included in (3), among those are apparantly the geographic variables in (4).

South East Asian countries seem to have had strong growth no matter the other variables. This fits well with observations of the so-called ”Asian Tigers” being a strong force of growth in the past 40 years.

Latin America does not seem to have the same directed growth, at least not within our sample. Like all the other variables these dummy variables have the possibility of having a ”growth bias”, as it may be likely that the countries for which one has data going back to the sixties may be the ones to focus efforts to attain growth, especially in the regions for which we have dummies.

In a regional sense one could argue that there should be one dummy for each continent or region in the world. Unfortunately the countries in my sample are too few for all to be accurately placed into regional dummy variables. I chose these two in particular because they are of a theoretical interesting nature. As mentioned the Asian Tigers had strong growth, as is shown, but also Latin America is of interest because of the varying economic policies there.

3.1.3 GDP in 2000

I wanted to check if being in the richest half of the countries was significantly contributing to growth. In a theoretical sense, is it so that GDP in 2000 could be a sign of many other factors contributing to growth. First I wanted to see if being member of the ”Rich Country Club” was in itself a factor contributing to growth. I made a dummy variable for this club[11]. I suppose one could a real ”club” such as the

[11] Richest 50% 2000

OECD, but I found this variable closer linked to my actual research question.

$$\text{GR19602000} = \beta_0 + [\ldots] + \beta_9 \text{Richest 50\% 2000} + \varepsilon \tag{5}$$

The effect is quite substantial and with a p-value of 0.00 it is significantly different from zero. Not only that, but when controlling for this, the effect from initial GDP is still significant and in (5) becomes stronger than in (4). Along with an increase in R^2 this seems to point towards there being just such an effect.

I also wanted to see if there was a direct link between how rich a country has become and whether that has a direct influence on the growth. It is interesting because in case of a strong coefficient it could be a sign of an opposite model than the neoclassic model. A model where everyone starts at the same point, but some simply grow faster than the others for other reasons.

$$\text{GR19602000} = \beta_0 + [\ldots] + \beta_{10} \text{Distance from the median GDP} + \varepsilon \tag{6}$$

Even though the coefficient is not very strong, it is significantly different from zero. This could be sign that there are many important causal variables that are left out of this model. To further support this claim, just adding the two last variables decrease this effect.

3.1.4 Investments and Public consumption

Many of the variables in my analysis are variables to control for effects outside the model. To even out any spurious effects one could say. It is, however, important to include variables explicit in the model as well. One of those is the population growth, already included. Two variables that are often forgotten in analyses it seems, but which I believe are of the more important ones are the level of government consumption[12] and investment[13].

In Figure 1 on page 2, investments are represented by *sy*. They are the investments of capital done within a country. In the words of Weil (2005) investments are

> the goods and services devoted to the production of new capital rather than [consumption] (p.29)

[12] Average CG is the average rate of public consumption in 1960, 70, 80, 90 and 2000

[13] Average CI is the average rate of investments in 1960, 70, 80, 90 and 2000

Without these kinds of investments there cannot be economic growth according to the model. The basic model is stateless, and government consumption therefore doesn't fit into it. To compensate for that, it might be a good idea to include government consumption as a part of the investments. One reason for this is that many of the areas affected by government consumption are in simple macroeconomic models under investments.

In addition there is an argument to be made for positive welfare state dynamics in a growth aspect, could a large rate of government consumption point towards a strong welfare state? According to Lindert (2002) this could mean a stable society, and favorable to higher levels of growth. One of the listed arguments in his article says that

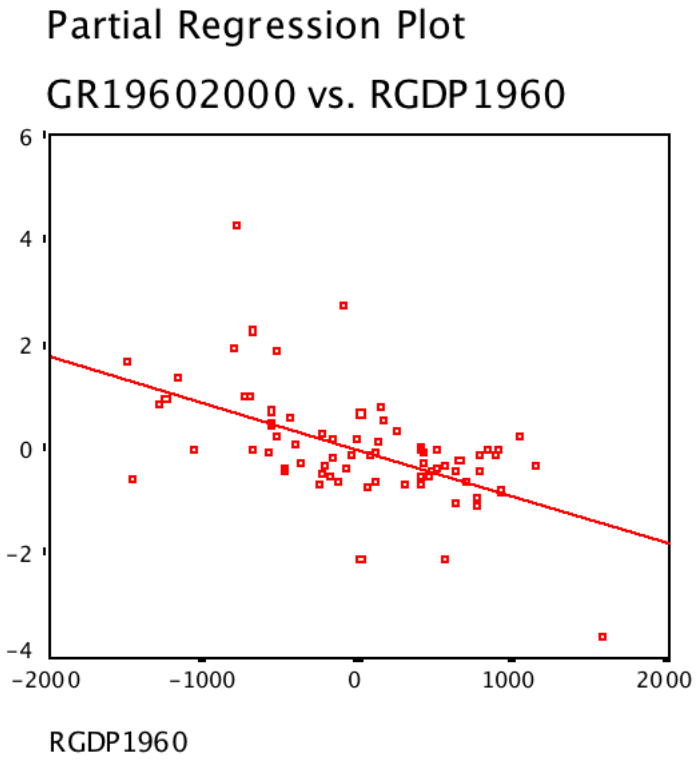
> [...] the high-budget welfare states choose a mix of taxes that is more pro-growth than the mix chosen in the United States and other relatively private-market OECD countries.(Lindert 2002)

There is also a case to be made for the opposite. Maybe a high rate of government consumption could signify high taxation, inefficient government spending or negative welfare state dynamics. This could, according to Lindbeck (2003), reduce efficiency and retard economic growth.

$$\text{GR19602000} = \beta_0 + [\ldots] + \beta_{11}\text{Average CG} + \beta_{12}\text{Average CI} + \varepsilon \tag{7}$$

The investments seem to have a slight positive effect, although far from significantly different from zero. It is hard to explain why they would not have a larger effect. It could be an inaccurate measure, maybe there have been severe fluctuations of the observations I have used or maybe some investments in some countries simply aren't as efficient as they could be.

Interestingly enough, the effect seems quite similar with government consumption. Here we may have a better explanation, as there is a theoretical basis to lean on. As mentioned above, in some economies government consumption can be very effective as a means of promoting growth, while in others it can be disastrous. This can be one explanatory factor for the relatively large standard error and lack of significance in the results.



3.2 How does the model stack up?

In comparison to Barro's model, I have not only broadened the time period for which the analysis has taken place, I have also brought in a few other variables. This seems to pay off as the model fit seems to be good, with an $R^2 = 0,814$ in (7). Several, but far from all, of the variables are significant, showing that there are many factors explaining economic growth. Many more than I have in this analysis.

The weaknesses of the statistical model I have presented are, like in any other regression model, important to have in mind. The fact that the dataset could be bias because of older data, as mentioned previously, is a major weakness. Also, there are clear problems in not being able to use perfect theoretical variables, variables like investment and government spending where the lines are unclear. Even the method may be problematic. Maybe a time-series regression would have been better in some way? I will not go further into that discussion. Given the limitations of both the data and of OLS regression, I think this model stacks up pretty well.

4 Observations

The goal of my analysis is to show whether the neoclassic model can be supported by empirical data. It seems clear, from the results I have gotten, that when control-

ling for other factors there is quite a bit of support for this model in the data. Just looking at the partial regression plot with the statistical results in mind, GDP seems to have a clear negative effect on growth. Like in Barro's (1991) analysis the effect is small but significant.

In relation to the theory, there seems to be, ceteris paribus, some explanatory power in the level of GDP per capita in year zero of the period in question, thus giving empirical support to the neoclassical model and to conditional convergence.

This does not however mean that the critiques are without foundation. As we show, the relationship between GDP and growth, however significant, is still merely a small part of the explanatory framework behind growth.

5 Conclusion

In the introduction I asked a fairly straight forward question, does the core argument of the neoclassic growth model hold in an empirical analysis? I say yes. Through replicating and improving the empirical work of Barro (1991) I believe I have shown just this. I have outlined why I chose to do the changes that were done to his theory, as well as the individual results. I have throughout this paper then come up with a solid statistical model with both logical, theoretical and empirical support.

This is an incredibly interesting topic warranting more research. Seeing as the neoclassical theory and its expansions are both highly recognized and quite simple I predict several more empirical studies in the future incorporating better variables, longer time-periods and more countries.

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A Regression results

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent Variable	GR19602000	GR19602000	GR19602000	GR19602000	GR19602000	GR19602000	GR19602000
(Constant)	1,66**	4,562**	4,89**	2,789**	2,586**	2,972**	2,398**
	(0,432)	(0,762)	(0,828)	(0,723)	(0,654)	(0,498)	(0,616)
RGDP1960	-1,42E-04	-2,94E-04*	-5,13E-04*	-2,32E-05	-4,46E-04*	-8,41E-04**	-8,89E-04**
	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)
PRIC15	3,23E-02	6,56E-03	1,23E-02	1,05E-02	5,55E-03	-9,63E-03	-1,15E-02
	(0,023)	(0,021)	(0,022)	(0,017)	(0,016)	(0,012)	(0,012)
SECC15	1,03E-02	5,51E-02	4,93E-02	3,89E-02	3,83E-02	6,18E-02*	4,90E-02
	(0,055)	(0,049)	(0,05)	(0,039)	(0,035)	(0,027)	(0,028)
HIC1515	6,12E-02	-2,16E-02	-1,33E-02	-5,37E-02	-9,26E-02	-0,149	-0,131
	(0,186)	(0,166)	(0,166)	(0,13)	(0,117)	(0,089)	(0,09)
POPGR19602000		-1,47**	-1,469**	-0,98**	-0,717**	-0,302	-0,372
		(0,334)	(0,334)	(0,269)	(0,252)	(0,2)	(0,21)
GDP60SQ			1,64E-08	-8,58E-09	1,51E-08	1,59E-08	1,99E-08
			(0,00)	(0,00)	(0,00)	(0,00)	(0,00)
South East Asia				3,856**	3,352**	2,813**	2,669**
				(0,608)	(0,563)	(0,433)	(0,445)
Latin America				-0,499	-0,467	0,272	0,361
				(0,428)	(0,386)	(0,311)	(0,319)
Richest 50% 2000					1,947**	1,189**	1,217**
					(0,493)	(0,388)	(0,4)
Distance from median gdp						2,13E-04**	2,05E-04**
						(0,00)	(0,00)
Average CG							2,44E-02
							(0,019)
Average CI							2,12E-02
							(0,021)
R^2	0,039	0,255	0,266	0,571	0,656	0,806	0,814
$\widehat{\sigma}$	2,086382885	1,851170374	1,85074712	1,437521997	1,296933707	0,981335333	0,976885012

∗Significant with α=0,05

∗∗Significant with α=0,01

Numbers in parentheses are standard error of estimate

B Country List

Country	Isocode	Country	Isocode	Country	Isocode
Algeria	DZA	Indonesia	IDN	Paraguay	PRY
Argentina	ARG	Iran	IRN	Peru	PER
Australia	AUS	Ireland	IRL	Philippines	PHL
Barbados	BRB	Israel	ISR	Portugal	PRT
Belgium	BEL	Italy	ITA	Senegal	SEN
Bolivia	BOL	Jamaica	JAM	South Africa	ZAF
Brazil	BRA	Japan	JPN	Spain	ESP
Cameroon	CMR	Jordan	JOR	Sri Lanka	LKA
Canada	CAN	Kenya	KEN	Sweden	SWE
Chile	CHL	Korea, Republic of	KOR	Switzerland	CHE
China	CHN	Lesotho	LSO	Syria	SYR
Colombia	COL	Luxembourg	LUX	Taiwan	TWN
Costa Rica	CRI	Malawi	MWI	Tanzania	TZA
Denmark	DNK	Malaysia	MYS	Thailand	THA
Dominican Republic	DOM	Mali	MLI	Togo	TGO
Ecuador	ECU	Mauritius	MUS	Trinidad &Tobago	TTO
El Salvador	SLV	Mexico	MEX	Turkey	TUR
Finland	FIN	Mozambique	MOZ	Uganda	UGA
France	FRA	Nepal	NPL	United Kingdom	GBR
Ghana	GHA	New Zealand	NZL	United States	USA
Greece	GRC	Nicaragua	NIC	Uruguay	URY
Guatemala	GTM	Niger	NER	Venezuela	VEN
Honduras	HND	Norway	NOR	Zambia	ZMB
Iceland	ISL	Panama	PAN	Zimbabwe	ZWE
India	IND				