Conditional Convergence: Evidence from the Solow Growth Model

Reginald Wilson
The University of Southern Mississippi

The Solow growth model indicates that more than half of the variation in gross domestic product per capita (GDP per capita) is attributed to savings rates and population growth. This paper investigates whether the Solow growth model also explains conditional convergence for three developing countries (Argentina, Cameroon, and Kenya), using a methodology that is consistent with Carlino and Mills (1996). The results suggest that the Solow growth model correctly predicts that an increase in the savings-investment ratio leads to capital accumulation. However, additional analyses indicate that an increase in capital per capita may not immediately follow a higher savings-investment ratio.

INTRODUCTION

Convergence is a process that occurs when a country approaches its steady state level. Dornbusch et al. (2001) suggest that there are two types of convergence: absolute convergence and conditional convergence. Absolute convergence is a product of the neoclassical growth theory, which assumes that countries will arrive at the same steady state income *if* they begin with equal savings rates, equal population growth, and equal technology access. Conditional convergence contends that countries with initial dissimilar savings rates and population growth have different steady-state incomes, but their growth *rates* eventually converge over time.

This paper presents a cross-cross study of three developing countries (Argentina, Cameroon, and Kenya) covering the time period 1981-2005 in order to test the theory of conditional convergence. The growth accounting equation is employed in order to examine the impact of each countries' capital accumulation and their savings with respect to their required investment in order to understand their progress towards their steady state economy. The paper concludes with a discussion regarding the possible underlying causes of each country's progress towards their steady state will be discussed.

HISTORICAL LITERATURE REVIEW

In 1956, Robert Solow created a model to predict steady-state income levels based on the contribution of a country's factors of production to income. Solow's study of United States' macroeconomic data from 1909-1949 led to the development of a growth equation that identified technical progress, increased labor supply, and capital accumulation as important determinants of GDP growth (Dornbusch et al., 2001). The Solow growth model indicated that more than half of the variation in GDP per capita is attributed to savings rates and population growth.

Barro (1991) developed a long-run growth rate model which used multiple explanatory variables – particularly beginning income levels – to explain conditional convergence. Barro studied 98 countries over a 26 year time period (1960-1985) using Summers Heston data (1995). The results of this model suggested that the growth of poorer countries increased faster than that of richer countries if human capital (proxied by school enrollment) exceeds that of more developed countries.

Mankiw et al. (1992) challenged the Solow Model, claiming that the rate of savings and population growth were weighted too heavily. Their augmented equation made human capital endogenous to the model, based on the theory that the accumulation of physical capital and population growth would have a greater effect on income levels when human capital is taken into account.[1] The augmentation of the model for human capital pointed to savings, education, and population growth as the major explanation of difference in international income. The model also reinforced the theory that countries converge at the rate predicted by the model (if population growth and physical capital are held constant), which suggests that the Solow model may explain international differences in GDP per capita.

Cho (1996) emphasized that conditional convergence occurs when "the growth rate appears to be negatively correlated with a country's income level." His research on conditional convergence examined the investment-to-GDP ratio and the population growth rate, chiefly because these variables contributed to an understanding of the impact of additional control variables on conditional convergence. The study explained that countries that have not reached their steady state will experience a slower growth over time. This theory is tested using countries from the Summers and Heston 1988 data set (excluding oil countries and seven countries with insufficient data). In order to test the endogeneity of control variables, the study compared the investment-to-GDP ratio and the rate of population growth of the three fastest- and three slowest-growing countries from 1960-1984. Consistent with Carroll and Weil (1993), the results indicated that savings is a function of growth, not a function of income.

Sala-i-Martin (1996) suggests that conditional convergence "relates to whether or not the cross-country distribution of world income shrinks over time" and absolute convergence "relates to the mobility of different individual economies within the given distribution of world income." Various empirical tests using the Summers-Heston data set concluded that endogenous growth models should be adopted in place of the neoclassical model. His research also finds that conditional convergence can be tested among countries if their steady-state economies are held constant by using either a substitute in place of the steady state, or by selecting countries that have realistic possibilities of achieving similar steady states. Consistent with Barro (1991), Sala-i-Martin's research concluded that the speed at which countries in the study experienced conditional convergence is approximately 2% per year (Sala-i-Martin, 1996).

In 2006, John W. Dawson studied international income convergence by using 29 countries, covering the time period of 1900-2001, using data from USA regions and subsets of OECD countries derived from studies performed by Angus Maddison in both 1995 and in 2003. The results of this study found that stochastic convergence was evident in 21 of 29 countries in the sample (Dawson, 2007).[2] Using Carlino and Mills' (1996) methodology to test conditional convergence, Dawson (2007) found that sixteen countries were progressing towards conditional convergence.

Hypotheses

The descriptive statistics in Table 1 provide baseline data to be used to compare the growth rates of three developing countries to a developed country (Canada). The trend in the descriptive statistics suggests that developing countries that do not invest their savings in capital accumulation may not experience as large of an increase in GDP growth rate as countries invest in capital accumulation, which leads to the first hypothesis:

H1: A higher savings-investment ratio leads to increased capital per capita

Developed countries (i.e. Canada), however, appear to experience higher GDP growth rates due to their relatively higher capital per capita growth rates. Based on these observations, the following hypotheses examine these observations:

H2: An increase in capital per capita and an excess of savings over investment leads to a higher GDP per capita.

H3 A higher savings-investment ratio and an increase in capital per capita, and a higher GDP per capita leads to a higher GDP per capita growth rate.

TABLE 1
DESCRIPTIVE STATISTICS
GROWTH RATES OF THE COUNTRIES 1981-2005

	Argentina	**Cameroon**	**Kenya**	**Canada**
Growth rate of GDP per capita (*y*)	0.52%	0.14%	0.08%	1.69%
Capital per capita (*k)*	1.43%	0.03%	0.002%	2.60%
Excess of Savings to investment ratio	0.89	1.03	37.47	2.17
Source: All data is from the WEO website except capita, which is from the OECD website.				

METHODOLOGY

The developing countries to be analyzed in this study are Argentina, Cameroon and Kenya. These countries are appropriate to re-examine the theory of conditional convergence due to their dissimilar savings rates, population growth, and technology access. Consistent with Cho (1996), the present study covers a 25 year period, and both studies use developing, non-oil producing countries.[3]

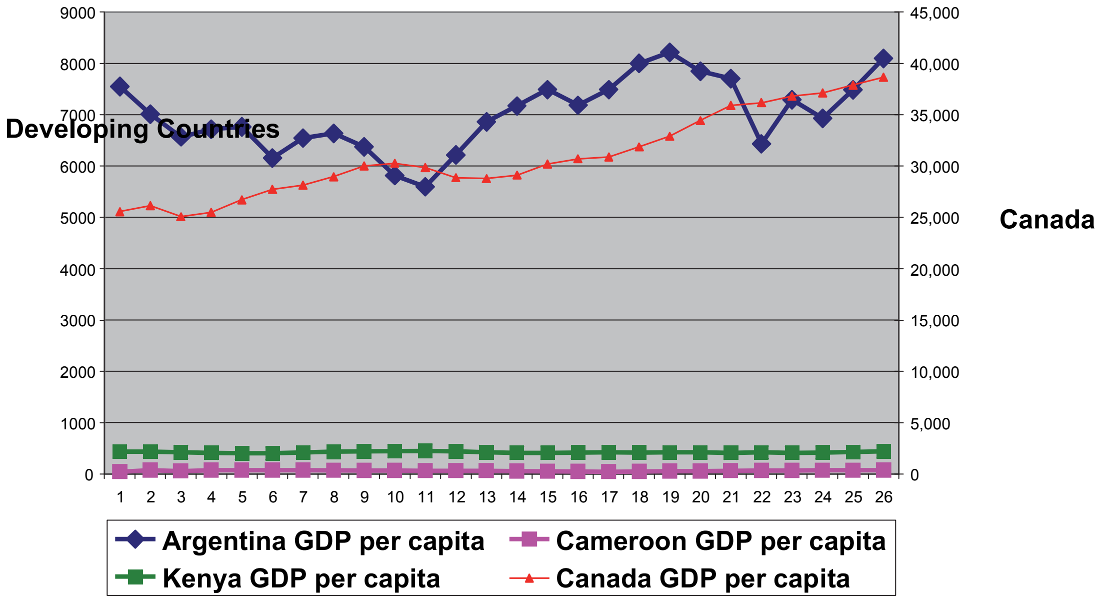
Data for the developing countries was researched in the World Economic Outlook website, the CIA World Factbook, and the International Financial Statistics volumes in the Jackson State University Library. However, these sources were incomplete, so the data for developing countries was derived from one source (World Development Indicators) for consistency purposes. Secondary data will be reported on the following factors for each country: the growth rate of GDP per capita (*y*), the capital-labor ratio (*k)*, the population growth rate (*n*), savings (*s'y*) and investment rates*,* and the rate of technological advance (*a*).

In order to test the neoclassical growth model, the sufficiency of capital per head for each country was tested by analyzing the rate of savings versus their investment. If the savings rate is higher than the required investment, and if capital per head increases, it can be assumed that there is a correlation between the two variables, and this explains each country's progress towards their steady state economies.

PRELIMINARY COUNTRY ANALYSES

Figure 1 demonstrates that each of the developing countries experienced an increase in GDP per capita. However, the developed country (Canada) outpaces the developing countries to the point that Cameroon and Kenya's GDP per capita appears to be stagnant.

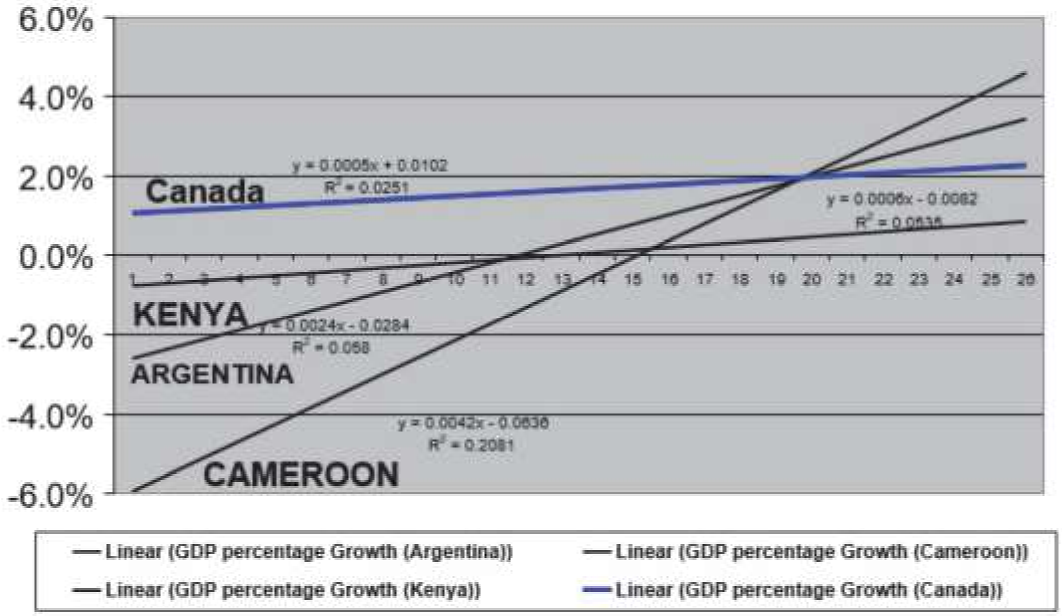
FIGURE 1
GDP PER CAPITA COMPARISON BY COUNTRY



Source: WEO Database and World Development Indicator Database

Figure 2 demonstrates that each of the developing countries' GDP per capita growth rates converged with the GDP per capita growth rate of Canada for a short period of time.

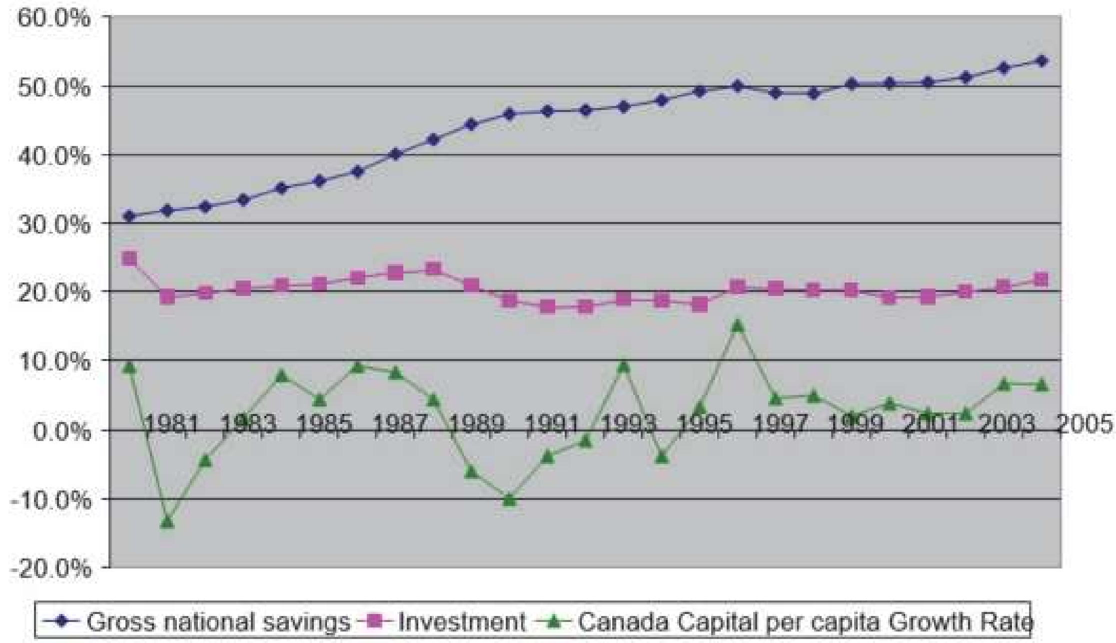
FIGURE 2
GDP PER CAPITA GROWTH RATE



Source: WEO Database and World Development Indicator Database

The neoclassical growth theory suggests that capital accumulation and capital per capita increase when a country's savings exceeds their investment, which leads to a resulting increase in a nation's standard of living. Figure 3 demonstrates that the capital per capita growth rate of Canada, whose capital per capita increased as its savings exceeded its investment, is best explained by the Neoclassical Growth Theory. As a result, Canada achieved a nearly zero growth rate as of the end of the time period of this study.

FIGURE 3
CANADA CAPITAL PER CAPITA GROWTH RATE

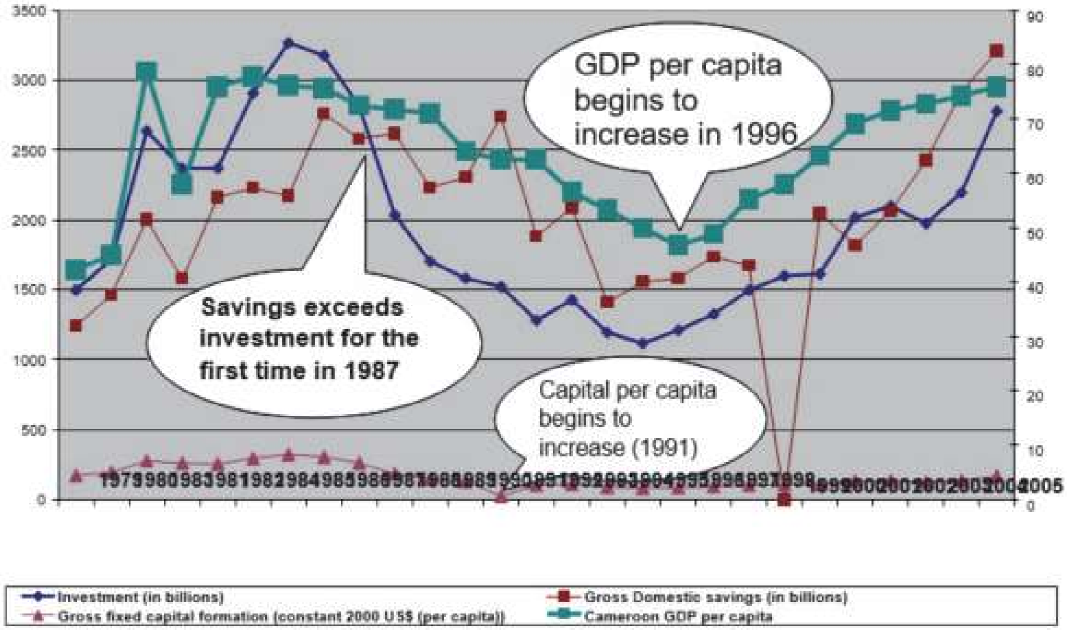


Source: World Economic Outlook Database

Cameroon

Figure 4 demonstrates that Cameroon, whose GDP per capita began to increase in 1996, experienced the largest increase in GDP per capita growth rate of all of the developing countries examined in the study.

FIGURE 4
CAMEROON CONVERENCE STUDY
(Investment and Savings in Billions)



Source: World Development Indicators Database

An analysis of the data reveals two waves of increase in capital per capita. The first wave occurred from 1980-1991, when capital per capita increased before a slight decrease. However, this increase was neither preceded by nor simultaneous with an increase in savings over investment. This event is unique to the Cameroon, not the other developing countries.

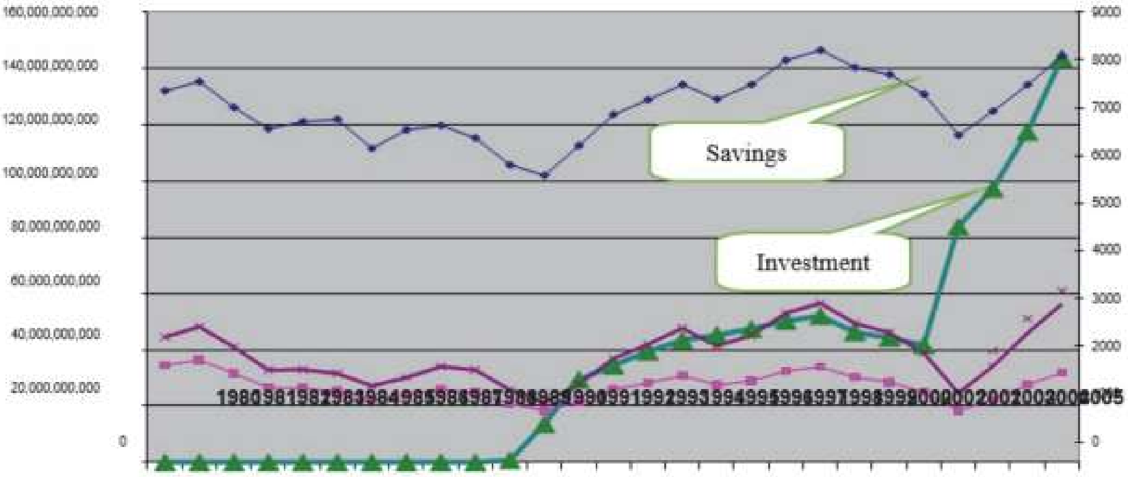
Prior to the second wave of increase in 1991, savings began to exceed investments in 1987. After capital per capita increased, it took five years for GDP per capita begin its increase (1996). There also appears to be a lag in the time that a change in capital per capita occurs following a change in the savings investment gap.

Although the scope of this study does not address the *use* of an excess of savings over investment, the data that suggests that the use of the excess savings for purchases other than capital did not improve a steadily decreasing GDP per capita. When the country's capital per capita began to rise in 1992, *then* GDP per capita began to increase (even though the increase did not occur instantaneously; it occurred in 1992). Thus, one may conclude that the use of savings over investment to fund capital will *eventually* lead to an increase in GDP per capita, and that not funding capital will not lead to an increase in GDP per capita.

Argentina

Argentina's GDP per capita also experienced two periods of significant increase: one in 1990 and the other in 2001 (Figure 5). Preceding the first increase in GDP per capita, savings never exceeded investment, and GDP per capita decreased simultaneously as capital per capita decreased. In 1990, savings over investment experienced minute increases. Capital per capita began to increase during this period (1991 – 1998). However increase did not last long; as savings fell below investment, both GDP and GDP per capita decreased. In 1992, Savings *significantly* exceeded investment, both GDP per capita and capital per capita increased immensely. These results indicate that an increase in Capital per capita simultaneously increases with GDP per capita when additional savings is used to increase capital.

FIGURE 5
ARGENTINA CONVERGENCE



Kenya

Kenya's economic data is presented in Figure 6. The data again proves that capital per capita growth and GDP per capita growth occur simultaneously.

FIGURE 6(A)
KENYA
SAVINGS-INVESTMENT GAP

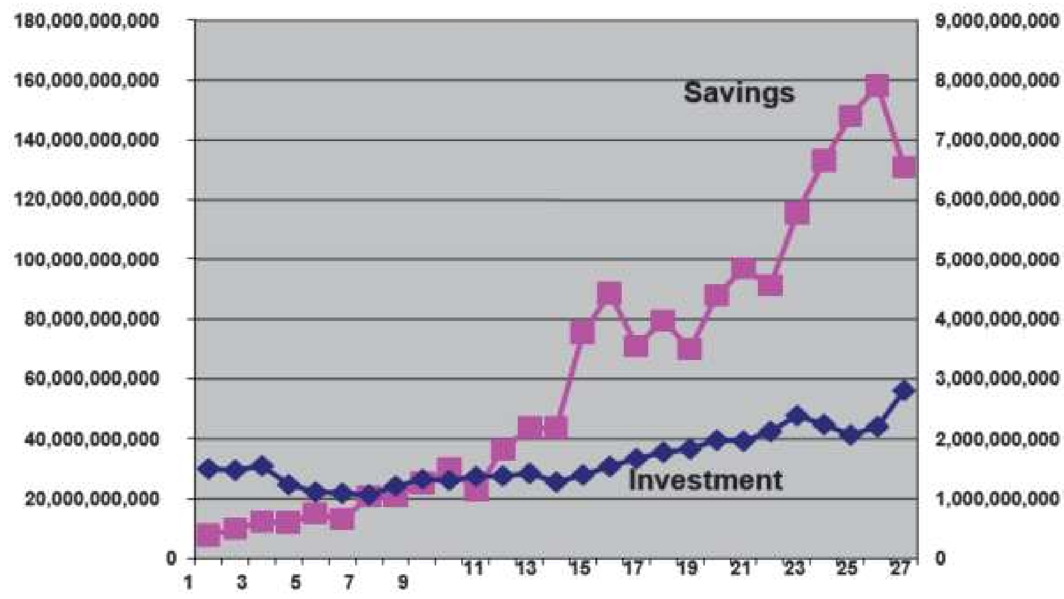
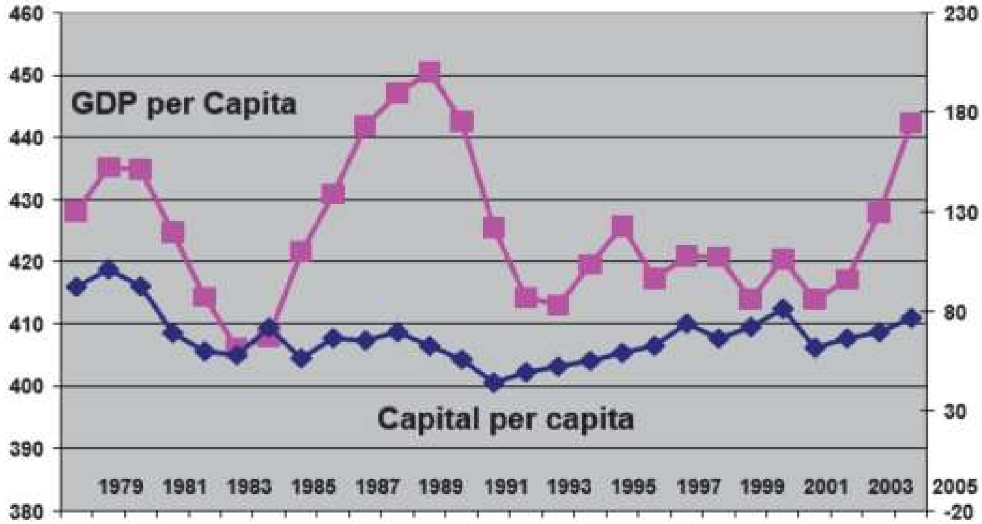


FIGURE 6(B)
KENYA CONVERGENCE



Source: World Development Indicators Base

Summary

While an increase in capital per capita does not mandate an increase in GDP per capita, it does appear to be a necessary component of an increase in GDP per capita. The same conclusion can be deduced from the savings investment gap. The scale of the secondary axis (investment) has been altered to gain a clear view of the fluctuations in investment, but in reality, savings exceeds investment in each year of the study; however, this does not dictate that an excess in savings leads to an increase in GDP per capita, but it gives a country the ability to increase its capital per capita.

MULTIVARIATE RESULTS

Capital per Capita Analysis

Hypothesis one examines whether a higher savings-investment ratio leads to increased capital per capita for developing countries. The data for Argentina, Cameroon, and Kenya was analyzed using a simple linear regression equation to test the relationship between capital per capita and the ratio of savings to investment. The following multiple regression equation is employed:

$$\text{Capital per capita} = 626 - [14.1 * \text{S-I Gap ratio}] \tag{1}$$

The equation yields sufficient evidence of the presence of regression, as indicated by the large F value (18.88) calculated in the ANOVA equation. The individual partial regression coefficients appear to be a good fit, as the t-ratio of both the constant (9.78) and the Savings-Investment Gap (-4.34) exceed their t-critical values of 1.6669 and -1.6669, respectively (all p-values < 0.005). It can be concluded from this analysis that there is an inverse relationship between capital per capita and the Savings-Investment Gap. If the Savings-Investment Gap increases, then Capital per capita decreases. These results do not support hypothesis one.

GDP per Capita Analysis

Hypothesis Two investigates whether both capital per capita and the Savings-Investment Gap ratio have a linear relationship with GDP per capita. The following equation was produced as a result of the analysis:

$$\text{GDP per capita} = -551 + 6.28 \text{ Capital per capita} + 14.7 \text{ S-I Gap ratio} \qquad (2)$$

This equation yields an overwhelming presence of regression ($F = 534.47$, $p < .005$). In addition, the equation is an adequate equation ($R^2 = 93.8\%$), and both variables exceed their t-critical values, with strong p-values. Based on the equation, one may conclude that GDP per capita has a linear relationship (direct) between GDP and the variables tested. Although GDP per capita grows with a higher S-I Gap ratio, the GDP per capita growth may yield different results from simply possessing a high S-I Gap ratio. Hypothesis two is supported.

GDP Growth Rate Analysis (Conditional Convergence)

Hypothesis three examines whether the following components lead to a higher GDP per capita growth rate: a higher savings-investment ratio, an increase in capital per capita, and a higher GDP per capita. The regression equation for the prediction of the GDP growth rate based on GDP per capita, Capital per capita, and the S-I Gap ratio is as follows:

$$\begin{aligned}\text{GDP Growth Rate} = 0.0697 \quad & - [0.000029 \text{ GDP per capita}] \\ & + [0.000121 \text{ Capital per capita}] \qquad (3) \\ & - [0.00165 \text{ S-I Gap ratio}]\end{aligned}$$

The results of this equation continue suggest that a direct relationship exists between the GDP growth rate and capital per capita. However, diminishing returns occurs as an increase in GDP per capita cannot continually occur in the long run, due to the inverse relationship of both an increase in GDP per capita and the S-I Gap ratio. These results infer that (1) the GDP per capita growth rate will increase only if capital per capita increases and that (2) savings that does not lead to a higher capital per capita will not increase the GDP per capita *growth* rate. Hypothesis three is partially supported.

CONCLUSION

Overall, the results of the study suggest that the Solow growth model correctly predicts that an increase of savings over investment leads to capital accumulation. In some cases (such as Cameroon), an increase in capital per capita may occur after the increase in savings over investment, but in other cases, it may occur simultaneously, as in the case of Argentina. Regardless of the case, capital per capita increased in each of the countries only after savings exceeded investment. In addition, the study empirically demonstrated that GDP per capita increases as both capital per capita increases and a positive Savings-Investment Gap ratio improves. However, capital per capita is the key to an increase in GDP growth rate, based on empirical testing. This study concludes that conditional convergence is possible if the countries can adjust their capital per capita to increase GDP per capita to catch up with more developed countries.

ENDNOTES

1. Their research also examined why countries' per capita income do not converge. Using data from Real National Accounts created by the Summers and Heston 1998 studies, they tested the theory that real income in countries with higher saving rates is higher than income in countries with lower savings rates, the author uses data from. The author used three samples of countries: 98 countries in which oil production is not the dominant industry, 75 intermediate countries (those whose income was based on very little primary data), and 22 OECD countries with populations greater than one million.
   The proxy for human capital – enrollees in secondary school – is obtained from the UNESCO yearbook. His research on the contribution of human capital to convergence revealed that his model accounted for nearly 80% of the difference in cross-country incomes (Mankiw et al., 1992). The results indicated that the model's variables of interest are highly significant for non-oil and intermediate countries, but less precise for OECD countries.
2. Stochastic convergence implies that shocks to the income of a given country relative to the average income across a set of countries will be temporary (Dawson, 2007).
3. Cho's (1996) study covered 1960-1984; the present study examines the years 1980-2005.

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