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Public Debt, Capital Accumulation, and Economic Growth: Is there a Nonlinear Relationship?

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Abstract

There have been many efforts to resolutely determine the net effects of public debt on economic growth. For various reasons, much of these efforts have focused on developed countries. The conclusions are varied -- with the balance swinging toward a negative linear effect of debt on economic growth. This paper focuses on the effects of debt on physical and human capital investments and economic growth. A Solow growth model is derived that incorporates public debt in the capital accumulation process. Cointegration and error-correction models are estimated for a panel data set. The empirical findings suggest a nonlinear effect of public debt on physical capital accumulation and economic growth. However, the optimal or threshold level is country specific.

JEL Codes: H63, E62, O47

Keywords: Economic growth, Public debt, developing countries, Error-correction model

1. Introduction

The Unites States Tax and Jobs Act of 2017 reduced personal income tax rates of the highest income earners in the U.S. from 39.6% to 37% for individuals and from 35% to 21% for corporations. This tax policy was the first of its kind since 1986 and is expected to increase the national debt by $2.29 trillion over the next ten years. Such a drastic increase in deficit spending and resulting diminished tax revenues to the federal government are sure to draw the ire of deficit hawks in the future. With a tribal political environment that has recently surfaced since the last election cycle -- it appears unlikely that the U.S. Congress will find the will and courage to increase the tax rate of corporations – making future fiscal policies more likely to be contractionary. As we know from elementary macroeconomics, this increase in public indebtedness brought on by deficit spending is likely to be a drag on economic growth.

According to the World Bank, excluding the highest income countries, the average country has increased its external debt level by approximately 10.6%[2] annually. The 2006 financial crisis has also had a deleterious effect of global debt levels. Over the period from 2006 to 2016, external

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[2] Raw data is from the data.WorkBank.org, calculation by author. It represents the geometric mean of external debt level from 1970-2016, in current US Dollars.

debt levels grew by an average annual rate of 9.61%[3]. Since 1970, public debt of the same countries has increased by only 8.71%, while economic growth increased by 8.89%. This cursory view suggests that debt is outpacing economic growth over substantial periods of time for the typical developing country. Debt has plagued countries by so much that the World Bank categorizes some countries as Heavily Indebted Poor Countries.

Researchers have delved into this topic with vigor. They have brought various econometric models to bear on this subject, while forwarding only a few theoretical models to explain the effects of debt on economic growth. Before I expand an economic model introduced by Coupet (2017), I will begin by reviewing a sample of the work conducted on this topic in the next section.

2. Literature Review

The public debt-economic growth question has drawn much interest in recent years[4]. Contributions have been deep and slightly varied. Its depth arises out of the many papers written on this subject in the last decade. This is partly explained by the appetite and use of public debt of many countries, as discussed in the previous section. Due to the heterogeneity of economies, most researchers have tried dissecting the data into clusters – namely groups of developed and developing countries. Along with heterogeneity, the question of the nonlinear effects of public debt on economic growth has also risen.

Reinhart and Rogoff's (2010) seminal work revealed a negative relationship between debt and economic growth. This cross-sectional analysis of developed and developing countries categorizes countries into four groups, by average debt levels from 1790 to 2007. Their results are mixed. The economies of highly indebted countries grow at lower levels than those with lower levels. While these results are cause for concerns for countries with higher debt levels, the study was largely empirical and lacked a theoretical foundation.

Using a panel data set of 38 developing and developed countries, Kumar and Woo (2015) also found heterogeneity in the effect of debt on economic growth. Debt coefficients differ based on country groupings. Nevertheless, Kumar and Woo found a non-linear relationship of debt and economic growth. They found a debt threshold level of 90%.

To control for a variety of factors, Checherita-Westphal and Rother (2012) used a panel data set of OECD countries in the Eurozone. They found a crowding out effect of central government debt on GDP. They concluded that an increase in debt put upward pressure on real interest rates, reducing investment and economic growth. Their instrument variable model resulted in a 70% debt threshold.

Mohamed (2013) performs a cointegration and error correction model using time series data from 1970 to 2010 on Tunisia. Mohamed finds unidirectional short and long-run causality of external debt on economic growth. The findings are robust with the inclusion of corruption and

[3] Ibid.

[4] Catherine Bonser-Neal (2015) provides a great review of the literature on this subject.

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other standard relevant variables. A test of nonlinearity reveals a concave short-run causal relationship on debt on economic growth.

Baglan and Yoldas (2013) used a fixed-effects panel of OECD countries over a period from 1954 to 2010 to find no effect of public debt and economic growth, with pooled data. They found that when the data are divided into low debt and high debt groupings, their results are statistically significant. The observed an 18% debt to GDP level to be optimum for the low debt sample. The high-debt sample indicated that a 10% increase in debt level, on average lead to a two to forty-eight basis point decrease in economic growth. Using a panel data of 105 developing and developed countries over a period from 1972 to 2009, Eberhardt and Presbitero (2015) used an error-correction model to test for nonlinearity. They concluded that, due to country diversity and heterogeneity, they could not find evidence of nonlinearity. Caner et al. (2011), using a panel data of 75 developing countries and 26 advanced economies, found a 77% threshold level of debt over the entire sample. However, over a sample of only developing countries, they found a 64% threshold level of debt to GDP.

Most contributions are empirical in construct. However, Coupet (2017) develops a classical economic growth model that incorporates exogenously public debt. Using data for a high-debt and low-debt OECD countries, he finds evidence of a negative effect of public debt on economic growth and gross physical capital stock. Consistent with other works in the literature, he finds negative long-run Granger causality of public debt on economic growth. However, he finds no evidence of nonlinearity. This research will add to the literature on neoclassical growth by extending Coupet's (2017) augmented Solow neoclassical growth model with human capital and public debt. I will develop the model in the next session, followed by a discussion on methodology and data. The results will be analyzed and follow with a brief conclusion.

3. The Model

Holding all else constant, deficit spending increases public debt and reduces national savings. A reduction in national savings increases real interest rates, making investments more expensive. If public capital spending is the objective of deficit spending, then initial levels of deficit spending increases output because marginal product of private sector inputs tends to exceed the marginal cost of borrowing. This leads to higher investment levels and output. However, consistent with the effects of increased debt on capital costs of firms, continued borrowing by the central government exposes its citizens to potential bankruptcy risks. This makes additional spending more difficult and further increases real interest rates. Marginal products of inputs begin to decrease – this subsequent decrease in productivity falls below the marginal cost of borrowing. This paper analyzes the nonlinear effect of public debt on an economy's physical capital accumulation and long run economic growth.

3.1 Government Debt and Capital Accumulation

The output effects of public debt for developing countries differ from mature, developed countries[5]. The central theme of this model is the assumption of a concave relationship of public debt and production function.

[5] For a concise analysis of public debt of OECD on output, see Coupet (2017). This model for developing countries deviates from the that of OECD countries by assuming non-linearity in the effects of debt on economic output.

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This assumption is consistent with the debt overhang theory in the literature. Nonlinear effects of debt on physical and human investments has its roots in the corporate finance literature. Well-functioning capital markets in developing countries associate risk with return on capital. Countries with minimal debt, finance capital projects, of both physical and human capital variety, by issuing debt instruments in the marketplace. The increase in liabilities incumber future household income for higher taxes to repay additional debts.

Because of diminishing returns to capital, additional increases in the debt level decreases marginal output for principally two reasons. First, at the margin, as the debt level rises, so does the country's perceived risk of default. A well-functioning capital market will incorporate the additional risk into the treasury's risk-free rate of return, putting upward pressure on firm-specific costs of capital. The second effect on economic output arises from reduced savings level that are a result of increased taxes. Initially, a country's economic output will rise by a greater amount than the tax encumbrances. However, as the country approaches its steady-state level of capital accumulation and output, output growth begins to fall. Nonlinearity is caused by two factors: a subsequent increase in a country's risk-free, caused by an increase in risk, and secondly, by a reduction in capital accumulation caused by eventual increase in taxation.

Relatively smaller economies that rely on net foreign investments and foreign direct investments to finance domestic investments are impacted in the same way – perhaps more so.
Defined structurally, debt-influenced shares of GDP are as,

$$\tilde{S}_K = S_K e^{\gamma(l - l^q)} \quad (1)$$

$$\tilde{S}_H = S_H e^{\gamma(l - l^q)} \quad (2)$$

Where a country's central debt level as a ratio of its GDP is measured as l and its risk-aversion is γ. Both γ and l are non-negative real numbers; $0 \leq \gamma \leq \infty$ and $0 \leq l \leq \infty$. A country with zero central debt (l = 0) will revert to zero-debt level capital accumulation, $\tilde{S}_K = S_K$ and $\tilde{S}_H = S_H$. As an economy begins to amass central government debt, its level of effect on capital accumulation will depend on γ, the risk-aversion parameter, and the level of l. The non-linear effect on the investment functions are as follows:

$$\frac{d\tilde{S}_K}{dl} = \gamma(1 - ql^{q-1}) S_K e^{\gamma(l - l^q)} \quad (3)$$

$$\frac{d\tilde{S}_H}{dD} = \gamma(1 - ql^{q-1}) S_H e^{\gamma(l - l^q)} \quad (4)$$

$\tilde{S}'_{Debt} > 0$; when l < $l^* = \frac{1}{q}^{\left(\frac{1}{q-1}\right)}$, and $\tilde{S}'_{Debt} < 0$; when l > $l^* = \frac{1}{q}^{\left(\frac{1}{q-1}\right)}$; where $\tilde{S}$ is the ratio of investments to GDP. Equations (3) and (4) show that a higher level of risk-aversion (γ) has a larger effect on capital accumulation. A country that is completely risk-neutral will have a value of $\gamma = 0$, again reverting to the Mankiw et al (1992) model.[6] This structural form captures the nonlinearity of the capital accumulation process. Beginning with zero debt, capital accumulation

[6] For example, a quadratic investment function will have an optimal (threshold) level of debt l^*= 50%.

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equals to national savings. As additional capital investments are made through deficit spending, debt total relative to GDP begin to rise. However, since the country has a relatively low level of debt, capital investments begin to rise. Depending on the country's political structure and debt sensitivity, the level of debt that makes additional borrowing varies per country. Beyond a certain endogenous level, the country's risk level begins to rise, making additional borrowing costlier and in some cases, unlikely. To finance increased debt levels, additional taxes are levied, further reducing capital expenditures at the margin. This process gives rise to a nonlinear effect on the capital accumulation process.

3.2 Effect of Public Debt on Economic Growth

We begin with the standard Augmented Solow model[7] with a Cobb-Douglas production function in intensive form, with constant returns to scale:

$$y_t = {k_t}^{\alpha} {h_t}^{\beta} \tag{5}$$

The per capita state equations are:

$$\dot{k}_t = \left(S_k e^{\gamma(l-l^q)}\right) y_t - (n + \delta_k + g) k_t \tag{6}$$

$$\dot{h}_t = \left(S_h e^{\gamma(l-l^q)}\right) y_t - (n + \delta_h + g) h_t \tag{7}$$

where s_K, s_H, δ_K, and δ_H are exogenous parameters that represent, respectively, shares of income that are allocated to physical capital investment, human capital investment, and depreciation rates of physical and human capital. Population is exogenously determined and defined as $L_t = L_0 e^{nt}$ so that population growth is constant over time, $(dL/dt)/L_t = n$. Multifactor productivity, defined as $A_t = A_0 e^{gt}$, has a growth rate of g. At steady state, the stock of physical and human capital levels remains constant and investments are made only to sustain themselves from population growth, technological growth, and depreciation. Solving the system of equation results in:

$$\ln\left(\frac{Y_t}{L_t}\right) = \ln(A_o) + gt + \frac{\alpha}{1-\alpha-\beta} ln(s_k) + \frac{\beta}{1-\alpha-\beta} ln(s_H) \\ - \frac{\alpha+\beta}{1-\alpha-\beta} \ln(n+\delta+g) + \frac{(\alpha+\beta)\gamma}{1-\alpha-\beta}(l-l^q) \tag{8}$$

Similarly, at steady-state level of physical and human capital per capita are as follows:

$$\ln\left(\frac{K_t}{L_t}\right) = \ln(A_o) + gt + \frac{1-\beta}{1-\alpha-\beta} ln(s_k) + \frac{\beta}{1-\alpha-\beta} ln(s_H) \\ - \frac{1}{1-\alpha-\beta} \ln(n+\delta+g) + \frac{\gamma}{1-\alpha-\beta}(l-l^q) \tag{9}$$

[7] For examples using the Cobb-Douglass functions as a production function, refer to Barro (1995), Mankiw et al (1992) and Coupet (2017) for a detailed account incorporating public debt.

$$\ln\left(\frac{H_t}{L_t}\right) = \ln(A_o) + gt + \frac{\alpha}{1-\alpha-\beta} ln(s_k) + \frac{1-\alpha}{1-\alpha-\beta} ln(s_H) - \frac{1}{1-\alpha-\beta}\ln(n+\delta+g) + \frac{\gamma}{1-\alpha-\beta}(l - l^q) \quad (10)$$

4. Methodology and Data

Using the national accounts data for non-OECD countries from the Penn world Table 9.0 and total debt data from the World Bank, I tested for a long-run relationship with the cointegration test using the variables relating to per-capita output and real physical capital per capita. Consistent with many of the studies conducted on the effects of debt on economic growth, I shall use the Engle-Granger Methodology (EGM). Using time series data developing countries, I shall try to test the significance of the structural model developed in the previous section of the paper. The EGM tests for long-run causality and equilibrium among multi-equation time series. In accordance to the EGM, I will use the specification defined in Equations (9) and (10) to estimate Error Correction Models. The EGM identify four steps to determine if a system of equations is cointegrated of order (1,1) and to estimate a vector error correction model, VECM.

1. Each series in the system equation is pretested for its order of integration. I will use a battery of unit-root tests for panel data on the levels of each series to test for unit roots. Using the general form of the Augmented Dickey-Fuller tests as follows, I use a five-panel data unit root test: Levin-Lin-Chu (LL), Im-Perasan-Shin (IPS), Breitung, Hadri LM, and Harris-Tzavalis to test for unit root:

$$\Delta y_{i,t} = a_0 + a_i + \delta t + \theta_t + \tau y_{i,t-1} + \sum_{j=2}^{p} \beta_i \Delta y_{i,t-1+j} + \varepsilon_{i,t} \; ;$$

where $\varepsilon_{i,t}$ is a stationary and serially uncorrelated disturbance term. The series is said to be integrated of order (1) if we cannot reject the null hypothesis of a unit root in the level equation but reject the hypothesis of a unit-root after first-differencing this equation. In short, the level equation must contain at least one unit root and its first difference is stationary. If all series are integrated of order (1), then the system of equations could be cointegrated of order (1,1).

2. After confirming that each series is I(1), we estimate the long-run equilibrium relationship by estimating the OLS equation:

$$\ln\left(\frac{GDP}{capita}\right)_{i,t} = \beta_0 + \sum \beta_i x_{it} + e_{it};$$

Where each x_i is an explanatory variables determined to be I(1) in the first step. The necessary next step in determining if the variables are CI(1,1) is by performing series of unit-root tests to determine if the error series, $e_{i,t}$, is stationary. If we can reject the null hypothesis of a unit root, we can conclude that the equation is cointegrated of order (1,1).

3. Given that the system of equations is CI(1,1), estimate the error correction model as follows:

$$\Delta\ln(\frac{GDP}{capita})_{i,t} = \beta_0 + \ln(\frac{GDP}{capita})_{i,t-1} + \alpha_1\hat{e}_{i,t-1} + \sum_{j=1}\alpha_{2i}\,\Delta\ln(INV)_{i,t-j} + \sum_{j=1}\alpha_{3i}\,\Delta\ln(HC)_{i,t-j} + \sum_{j=1}\alpha_{4i}\,\Delta\ln(n+\delta)_{i,t-i} + \sum_{j=1}\alpha_2\,Debt_{i,t-j} + \epsilon_{i,t}$$

Where $\epsilon_{i,t}$ is stationary and serially uncorrelated disturbance term. OLS will be used to estimate the included parameters.

4. Long-run equilibrium and the speed of adjustment will be determined by the coefficient of $\hat{e}_{i,t-1}$. According to Enders (1995) and Engle and Granger (1987), long-run equilibrium requires that the coefficient is negative and statistically significant. The value of the coefficient provides the annual path toward equilibrium GDP in the long-run.

Adequate lag length included in the regression can be confirmed with a test of the disturbance term, $\epsilon_{i,t}$. If the error series is serially uncorrelated and indicative of a white noise process, then the included lag lengths are adequate.

To maximize the number of observations and increase the power of the tests, I use the full sample of developing countries[8] to analyze the effect of relative public debt (public debt/real GDP per capita) on physical capital and economic growth. National accounts data are taken from the Penn World Table 9.0 and central government debts are taken from the World Bank. Data description are found in Table 1.

Table 1: Data Description

Variable	*Description*	*Source*
RGDP	Output-side real GDP at chained PPPs (in mil. 2011 US$) per capita	Penn World Table 9.0
S_K	Share of gross capital formation at current PPPs	Penn World Table 9.0
Hc	Human capital index based on years of schooling and returns to education.	Penn World Table 9.0
Pop	Population (in millions)	Penn World Table 9.0
N	$(Pop_t - Pop_{t-1})/Pop_{t-1}$	Author (Using PWT 9.0)
Δ	Average depreciation rate of the capital stock	Penn World Table 9.0
Debt	Central government debt, total (% of GDP). Foreign and domestic debt.	International Monetary Fund, Government Finance Statistics Yearbook and data files, and World Bank and OECD GDP estimates.

[8] The full sample consists of a balanced panel dataset of the following countries: Guatemala, India, Iceland, Jordan, Maldives, Mauritius, Philippines, Singapore, Thailand, &Tunisia; for years 1991-2011. The period was selected to retain a balanced dataset, while maximizing the number of observations.

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A graphical depiction of each series is found in Figure 1. With few exceptions, each series appears to be stationary for most countries. Human capital index series appears to have a time trend inherent for all countries. We will conduct formal unit-root tests to arrive at our conclusions.

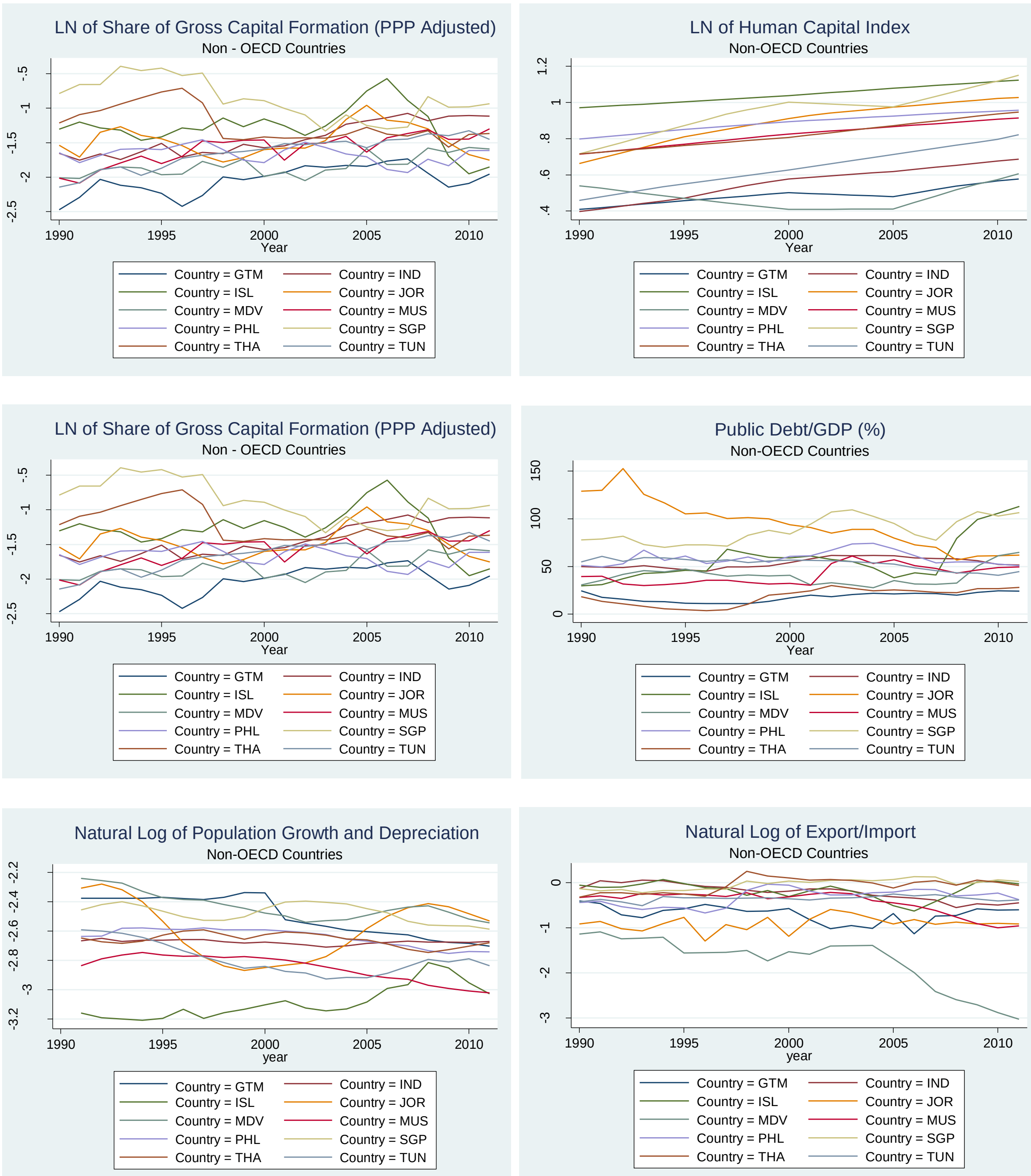

Figure 1: Graphs of Data for Various Countries

5. Results and Discussion

A necessary condition for cointegration in the EGM is for the existence of a unit root in the levels of each variable and stationarity in their first differences. Table 2 is a summary of the results of five unit-root tests of panel data. It is important to note that, excluding the Hadri LM test, under the null hypothesis, all models assume a unit root. A series is said to be integrated of order 1 if a minimum of three of five unit root tests fails to reject the null hypothesis of a unit root in its level and rejects the null hypothesis of its first difference. The natural log of real GDP per capita variable strongly rejects the existence of no-unit root by the Hadri LM test at the 1% significance level and fails to reject the existence of a unit root with the remaining tests. When compared to the first difference of the same variable, four of five tests report the rejection of a unit root. We can conclude that the level of the natural log of real GDP variable is integrated of order 1, I(1). Using the same criterion for the remaining variables, we conclude that the natural logs of human capital (LN (HC)) and natural log of population growth and depreciation (Ln (n & delta)) are not I(1). According to the EGM, the variables cannot be cointegrated (of order 1,1). We can therefore conclude that there is no long-run relationship among the variables (Enders, 1995).

Table 2: Panel Unit Root Tests for Developing Countries

	Panel Unit Root Tests for Developing Countries					
	LLC (Adj. t)	Breitung (λ)	I-P-S ($\overline{W}_t$)	Hadri LM (Z)	H-T (ρ)	Order of Integration
Ln (rGDP)	-0.35	2.65	0.72	18.58***	0.80	I(1)
Δ Ln (rGDP)	-2.51***	-3.91***	-2.05**	3.00***	0.27***	I(0)
Ln (INV)	-2.82**	-0.27	-1.42	19.12***	0.80	I(1)
Δ Ln (INV)	-6.16***	-3.18***	-6.54***	-0.77	0.01***	I(0)
Ln (HC)	-0.02	-0.31	1.82	37.39***	0.98	---
Δ Ln (HC)	-0.93	-0.05	0.98	21.91***	0.87	---
Ln (n & delta)	-5.33***	-0.90	-1.78**	20.10***	0.92	I(0)
Δ Ln (n & delta)	-4.07***	-2.87***	-4.15***	5.26***	0.51***	I(0)
Ln (debt/GDP)	0.63	-0.44	1.39	25.05***	0.92	I(1)
Δ Ln (debt/GDP)	-4.32***	-3.02***	-4.64***	-0.29	0.08***	I(0)
Ln (x/m)	0.15	-0.15	0.25	24.30***	0.91	I(1)
Δ Ln (x/m)	-5.38***	-5.57***	-5.86***	-0.48	-0.16***	I(0)
Ln (physcap)	1.53	1.11	3.54	37.14	1.00	I(1)
Δ Ln (physcap)	-3.38***	-2.05**	-3.65***	5.43***	0.50***	I(0)

Westerlund (2008) ECM Panel cointegration tests were also conducted. They confirm the EGM results of no-cointegration. The results are found on Table 3. The p-values of all four tests fail to reject the null hypothesis of no-cointegration among the four variables included in Table 2 (omitting Ln (x/m)).

Both EGM and Westerlund tests reject the null hypothesis of cointegration among the included variables for the included 10-member countries. Rejection of cointegration among the 10 states indicates that a subset of the 10 states of the panel data is not cointegrated with the others. Therefore, I will conduct a test of cointegration for each state (country) to ascertain which ones, if any, are cointegrated.

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Table 3: Westerlund ECM Cointegration Test

Westerlund ECM Panel Cointegration Tests			
Statistic	Value	Z	P
G(t)	-0.90	3.31	1.00
G(a)	-0.18	4.31	1.00
P(t)	-2.81	1.82	0.97
P(a)	-0.45	2.45	0.99

$H_0: No\ cointegration$

With 10 series and 4 covariates

5.1. Cointegration Among Sub-Sample

Augmented Dickey-Fuller, Phillips-Peron, and modified GLS Dickey-Fuller unit root tests were conducted for each country of the 10-member subsample. These results are found in Tables A1 through A10 of Appendix A. Implementing the previous strategy on the full sample of developing countries, cointegration requires passing two of three stated unit root tests. Only two of ten countries' variables are CI(1,1): Guatemala and Iceland. Therefore, these two states can be combined to form a subset of developing countries to form a panel to increase the power of tests.

Unit root tests are conducted for the Guatemala and Iceland subset of developing countries. The results are included in Table 4. Again, using a battery of unit root tests, we can accept the null hypothesis of a unit root in the levels of each variable (we reject it in the Hadri LM test), but reject the null hypothesis of a unit in the differences of all variables. This suggests that all variables are I(1).

Table 4: Unit Root Tests for Guatemala and Iceland Subset of Developing Countries

Guatemala and Iceland Countries Panel Unit Root Tests						
	LLC (Adj. t)	Breitung (λ)	Im-Perasan-Shin ($\overline{W}_t$)	Hadri LM (Z)	H-T (ρ)	Order of Integration
Ln (rGDP)	0.91	1.66	1.89	16.93***	0.97	I(1)
Δ Ln (rGDP)	-2.62***	-0.91	-2.27**	0.61	0.39***	I(0)
Ln (INV)	-1.73**	-1.84**	-1.55	2.76***	0.79	I(1)
Δ Ln (INV)	-3.28***	-1.83**	-2.88***	0.42	0.34***	I(0)
Ln (HC)	0.74	-0.44	2.52	16.92***	1.01	I(1)
Δ Ln (HC)	-1.08**	-0.66	-0.28	1.22	0.70**	I(0)
Ln (n & delta)	-0.21	0.03	0.86	14.23***	0.94	I(1)
Δ Ln (n & delta)	-1.72**	-2.85***	-1.68**	-0.49	0.15***	I(0)
Ln (debt/GDP)	1.55	-0.23	1.23	7.91***	0.99	I(1)
Δ Ln (debt/GDP)	-1.40*	-1.92**	-1.57**	0.58	0.21***	I(0)
Ln (x/m)	-1.57*	-1.98**	-1.17	3.07***	0.60***	I(1)
Δ Ln (x/m)	-2.39***	-1.87**	-2.22**	-0.55	-0.19***	I(0)
Ln (physcap)	0.70	0.42	1.55	17.89***	1.00	I(1)
Δ Ln (physcap)	-3.86***	-1.24*	-5.84***	-0.49	0.06***	I(0)

LLC, Breitung, H-T, and Im – Perasan -Shin panel unit root tests have as a null hypothesis:
$H_0: Panels\ contain\ unit\ roots;\ \ H_A: panels\ are\ stationary$Hadri LM panel unit root test:
$H_0: All\ panels\ are\ stationary;\ \ H_A: some\ panels\ contain\ unit\ root$
***1% level significance, **5% level significance, *10% level significance; Countries in panel: Guatemala & Iceland
Years included: 1990- 2011

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To determine if they are cointegrated, we run OLS of Equations 8 and 9 beginning with baseline models without the debt variable. These results are included in Tables 5 and 6. Beginning with the baseline 1 of Table 5, coefficients of human capital investments, population growth and depreciation are statistically significant at the 1% level. To determine if those variables are cointegrated, we test for stationarity of the residuals. Both Breitung and LLC unit root tests reject the null hypothesis of a unit root at the 5% level. We can conclude that physical capital per capita and population growth and depreciation are CI(1,1). When the debt variable enters the equation, the coefficient of the log of investments is now statistically significant and carries the correct sign. To fully test the validity of Equation 8, nonlinearity in the debt variable, we include the squared value of the debt variable.

With stationarity of the residuals as indicated by the results of the unit-root tests, we can conclude there is a long-run equilibrium between physical and human capital investments and physical capital formation per capita. However, because the coefficients of debt and debt squared variables are statistically insignificant, we can rule out the null hypothesis that debt influences real physical capital formation per capita.

Table 5: Cointegration Test of Physical Capital per Capita -- Guatemala and Iceland

	Subset Panel Cointegration Equation: Ln (K/cap)$_t$				
	(1)	(2)	(3)	(4)	(5)
Constant	5.289	3.012	3.377	3.387	4.054
	(0.490)***	(0.532)***	(0.628)***	(0.613)***	(0.768)***
Ln $(S_K)_t$	0.114	0.139	0.210	0.170	0.513
	(0.081)	(0.086)	(0.092)**	(0.096)*	(0.184)***
Ln $(hc)_t$	3.981	5.594	5.128	5.176	4.866
	(0.328)***	(0.492)***	(0.432)***	(0.1475)***	(0.487)***
Ln $(n + \delta)_t$	-0.833	-1.029	-1.059	-0.983	-1.030
	(0.236)***	(0.208)***	(0.188)***	(0.283)***	(0.257)***
Debt/GDP$_t$	---	---	0.002	0.007	0.005
			(0.002)	(0.009)	(0.009)
$(Debt/GDP_t)^2$	---	---	---	-0.00004	-0.0000†
				†(0.000)	(0.000)
Ln (x/m)	---	---	---	---	0.413
					(0.230)*
State Dummy	N	Y	Y	Y	Y
	Diagnostics				
R^2	0.994	0.994	0.994	0.994	0.994
# of obs	42	42	42	42	42
LLC (Adj. t)	-2.102**	-3.719***	-3.986***	-3.770***	-3.705***
Breitung (λ)	-1.931**	-3.141***	-3.320***	-3.215***	-3.105***

Panel: Guatemala & Iceland

Heteroskedastic -robust error in parentheses
*** 1% statistical significance
** 5% statistical significance
*10% statistical significance
Periods: 1991-2011 (21)
†rounded non-zero number

I perform a similar analysis with the log of real GDP per capita as the dependent variable. These results are found on Table 6. Specifications 1 and 2 are a baseline cases with and without the state dummy variable. The state dummy variable, specification 2, marginally improves the model, as suggested with the increase in adjusted R^2 from 0.998 to 0.999. The null hypothesis of a unit root in the residuals is rejected at the 1% level of significance. The inclusion of the debt variable in specification #3 retains the significance of the coefficients of physical and human capital investments. The coefficient of population growth and depreciation retains its sign but loses it statistical significance. This is a sign that the linear effect of debt is mis-specified. When the square of the debt variable is also included, the model improves significantly. The positive value of the debt coefficient and the negative coefficient of the squared debt variable suggest that the effect of debt is concave -- with an optimal debt/GDP ratio of 8.75%[9]. Cointegration of relevant variables continues to be supported by the results of unit root tests. To test robustness of the model, the ratio of export over imports is included in specification #5. The model shows signs of robustness, with coefficients of all variables remaining statistically significant, with appropriate signage.

Table 6: Cointegration Test of Real GDP per Capita

	Subset Panel Cointegration Equation: Ln (GDP/cap)$_t$				
	(1)	(2)	(3)	(4)	(5)
Constant	6.766 (0.135)***	7.051 (0.180)***	7.178 (0.206)***	7.190 (0.180)***	7.202 (0.219)***
Ln $(S_K)_t$	0.169 (0.031)***	0.166 (0.028)***	0.190 (0.031)***	0.140 (0.031)***	0.146 (0.067)**
Ln $(hc)_t$	3.183 (0.063)***	2.981 (0.138)***	2.819 (0.164)***	2.879 (0.160)***	2.874 (0.183)***
Ln $(n + \delta)_t$	-0.204 (0.046)***	-0.179 (0.045)***	-0.189 (0.042)	-0.092 (0.052)*	-0.093 (0.056)
Debt/GDP$_t$	---	---	0.001 (0.0006)	0.007 (0.002)***	0.007 (0.003)**
$(Debt/GDP_{t)})^2$	---	---	---	-0.00004 †(0.000)***	-0.0000† (0.000)**
Ln (x/m)	---	---	---	---	0.007 (0.058)
State Dummy	N	Y	Y	Y	Y
	Diagnostics				
R^2	0.998	0.999	0.999	0.999	0.999
# of obs	42	42	42	42	42
LLC (Adj. t)	-3.691***	-4.144***	-4.321***	-4.388***	-4.428***
Breitung (λ)	-3.181***	-3.440***	-3.494***	-3.549***	-3.565***

Panel: Guatemala & Iceland

Heteroskedastic -robust error in parentheses

*** 1% statistical significance
** 5% statistical significance
*10% statistical significance

Periods: 1991-2011 (21)

†rounded non-zero number

5. 2 Error - Correction Models

We run an error-correction model to test for long-run Granger causality, error-correction and equilibrium convergence. The results are found in Table 7. Again, Specification #1 is a baseline

[9] $y = .0007l - .0004l^2; \rightarrow \frac{dy}{dl} = .007 - .0008l = 0; \rightarrow l^* = 8.75\%$

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model to test for long-run relationship between physical capital per capita and physical and human capital investments, and public debt. The error-correction term, $\hat{\varepsilon}_{t-1}$, is negative and statistically significant at the 5% level. This confirms a long-run equilibrium among physical and human capital investments, population growth and depreciation, and public debt. An absolute value of 35.4% implies that 35.4% of disequilibrium from the previous year deviation from equilibrium is made up in the current year. This is the model's error-correction, or convergence rate. The coefficient of the debt variable is positive and statistically significant. This implies that increases in debt Granger causes changes in physical capital per capita. Specifically, a 1% increase in the debt ratio "causes" an increase in physical capital per capita by .3%. The inclusion of the square of debt variable decreases the model's R^2 and its coefficient is not statistically different from zero. Therefore, specification #2 is inferior to #1. We have verified that the first difference of the physical capital. The unit root tests, Breitung and LLC, reject the null hypothesis of a unit root in the residuals of the model – they are stationary. This is further evidence of cointegration in the variables which are all I(0). A p-value of .01% rejects the null hypothesis that the residuals of specifications #1 and #2 are normally distributed.

Table 7: Error-Correction Models -- Guatemala and Iceland

	Non-OECD Subset Error-Correction Models			
	$\Delta ln(K/cap)_t$		$\Delta ln(GDP/cap)_t$	
	(1)	(2)	(3)	(4)
Constant	0.006	0.009	†-0.000	-0.001
	(0.020)	(0.020)	(0.007)	(0.007)
$\hat{\varepsilon}_{t-1}$	-0.354	-0.329	-0.511	-0.596
	(0.131)**	(0.127)**	(0.109)***	(0.113)***
$\Delta\, ln(GDP/cap)_{t-1}$	---	---	0.391	0.343
			(0.121)***	(0.120)***
$\Delta\, ln(K/cap)_{t-1}$	0.403	0.372	---	---
	(0.156)**	(0.158)**		
$\Delta Ln\,(S_K)_t$	0.053	0.042	0.070	0.057
	(0.063)	(0.067)	(0.024)***	(0.024)**
$\Delta Ln\,(HC)_t$	1.737	1.649	1.75	1.952
	(1.856)	(1.877)	(0.682)**	(0.657)***
$\Delta Ln\,(n+\delta)_t$	0.128	0.156	-0.029	-0.006
	(0.231)	(0.229)	(0.080)	(0.075)
$\Delta(Debt)_t$	0.003	0.005	†-0.000	0.002
	(0.001)**	(0.005)	(0.001)	(0.002)
$\Delta(\text{Debt})\text{t}^2$	---	†-0.000	---	†-0.000
		†(0.000)		†(0.000)
	Diagnostics			
Adj. R^2	0.265	0.239	0.555	0.597
Breitung (λ)	-2.53***	-2.58***	-4.236***	-3.97***
LLC (Adj. t)	-2.095**	-2.068**	--3949***	-3.695***
Normality Test (Prob > χ^2)	0.0001	0.0001	0.893	0.687

Robust standard error in parentheses
***1% statistical significance
**5% statistical significance
* 10% statistical significance

Specifications #3 and #4 are error-correction models for real GDP. The error-correction terms of these models highlight the long-run relationship that exists between real GDP, physical and human capital investments, population growth, and debt. Moreover, as widely reported in the

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literature, physical and human capital investments Granger cause higher levels of GDP. A negative and statistically significant coefficient of the error-correction terms corroborate cointegration in the variables – the models are CI(1,1). Approximately 60% of the deviation from long-run equilibrium in the previous year is made up in the current year. This is a very fast convergence rate. Stationarity of the residuals is accepted by rejecting the null hypothesis of a unit root – a necessary condition for cointegration. Unlike the models for physical capital (specifications #1 and #2), the residuals of the real GDP models are normally distributed.

5.3 Model Consistency

As a test of consistency, we will test the model for each country of the sub-sample. The cointegration test for Iceland is found in Table 8. Consistent with the two-country sample of developing countries, the baseline model for Iceland suggests that real GDP is cointegrated with investments in physical and human capital investments and depreciation and population growth.

Table 8: Real GDP Cointegration Tests for Iceland

Iceland Cointegration Equation: Ln $(GDP/cap)_t$				
	(1)	(2)	(3)	(4)
Constant	8.628	8.929	8.461	8.891
	(0.519)***	(0.5648)***	(0.867)***	(0.901)***
Ln $(S_K)_t$	0.167	0.249	0.178	-0.023)
	(0.028)***	(0.056)***	(0.057)***	(0.057)
Ln $(hc)_t$	2.345	1.910	2.241	1.892
	(0.276)***	(0.363)***	(0.461)***	(0.510)***
Ln $(n + \delta)_t$	0.115	0.065	0.097	0.213
	(0.084)	(0.110)	(0.122)	(0.128)
$Debt/GDP_t$	---	0.002	0.007	0.008
		(0.0009)*	(0.003)**	(0.003)**
$(Debt/GDP_{t)})^2$	---	---	†-0.0000	-0.0000
			†(0.000)*	†(0.000)**
Ln (x/m)	---	---	---	-0.290
				(0.160)*
Diagnostics				
R^2	0.898	0.910	0.933	0.939
# of obs	21	21	21	21
Adj. Dickey-	-1.913	-1.877	-2.372	-2.755
Fuller	(-1.60)*	(-1.60)*	(-1.950)**	(-2.660)***
Phillips-Perron	-2.131	-2.816	-4.052	-4.785
	(-1.95)**	(-2.660)***	(-2.660)***	(-2.660)***

Robust standard error in parentheses * 10% statistical significance
**5% statistical significance
***1% statistical significance

The adjusted Dickey-Fuller test rejects the null hypothesis at the 10% level and Phillips Perron at the 5% level. The inclusion of the debt variable improves the model (R^2 =0.91). While retaining the statistical significance of coefficients of the investment variables, the coefficient of the debt variable is positive and statistically significant at the 5% level. Specification #3 tests for nonlinearity in the debt variable. Concavity in the debt variable is established. The level, sign, and significance of the debt variable coefficient remains at 0.007. The coefficient of the debt square variable is also negative and statistically significant at the 10% level. Albeit relatively weak evidence, we observe concavity in the effects of debt on per capita GDP. Contrary to the small-

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sample results on optimal[10] debt level, the result for Iceland suggest that the optimal debt level is 87.5% -- 10 times greater than that of the subsample. The results hold up when the ratio of export to imports variable enters the model. Most importantly, stationarity of the residuals suggests long run equilibrium in the levels of real GDP per capita and all relevant variables.

The ECM of the log of GDP is included in Table 9. The results are like the full subsample model. The error correction terms are negative and statistically significant. There is a long-run relationship between real GDP and relevant variables. We include the second lag of the difference of the real GDP to obtain residuals that are not autocorrelated. The alternate Durbin-Watson p-value of 0.83, does not allow us to reject the null hypothesis of no autocorrelation. Both unit root statistics allow us to reject the null hypothesis of a unit root at the 1% level.

Table 9: Error Correction Model for Iceland

Iceland Error-Correction Models		
	$\Delta ln(GDP/cap)_t$	
Constant	†-0.085	-0.110
	(0.103)	(0.094)
$\hat{\varepsilon}_{t-1}$	-0.653	-.846
	(0.207)***	(0.222)***
$\Delta\ ln(GDP/cap)_{t-1}$	0.432	0.375
	(0.196)**	(0.175)*
$\Delta\ ln(GDP/cap)_{t-2}$	0.028	0.050
	(0.215)	(0.204)
$\Delta Ln\ (S_K)_t$	0.123	0.101
	(0.041)***	(0.040)**
$\Delta Ln\ (HC)_t$	13.257	16.69
	(13.84)	(12.81)
$\Delta Ln\ (n + \delta)_t$	-.058	-0.063
	(0.156)	(0.141)
$\Delta(Debt)_t$	†-0.0003	0.005
	(0.0007)	(0.003)
$\Delta(Debt)_t{}^2$	---	†-0.000
		†(0.000)
Diagnostics		
Adj. R^2	0.56	0.65
Alt. D.W. P value	0.76	0.83
Adj. D-F	-3.257	-3.54
	(-2.660)***	(2.660***
Phillips-Perron	-3.929	-3.791
	(2.660)***	(-2.660)***
Normality Test (Prob $> \chi^2$)	0.893	0.687

Robust standard error in parentheses * 10% statistical significance
**5% statistical significance
***1% statistical significance

For completeness, the cointegration test of real GDP per capita for the Guatemala sample are found in Table 10. The baseline models support cointegration, using the EGM used in previous

[10] $y = .0007l - .00004l^2; \rightarrow \frac{dy}{dl} = .007 - .0008l = 0; \rightarrow l^* = 8.75\%$

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samples. However, the inclusion of linear and quadratic debt variables is statistically insignificant. Thus, debt appears to be insignificant in explaining long-run equilibrium real GDP per capita.

Table 10: Cointegration Test for Guatemala

Guatemala Cointegration Equation: Ln (GDP/cap)$_t$				
	(1)	(2)	(3)	(4)
Constant	6.477	6.374	6.601	6.667
	(0.114)***	(0.183)***	(0.226)***	(0.255)***
Ln $(S_K)_t$	0.010	0.108	0.122	0.161
	(0.025)***	(0.025)***	(0.028)***	(0.049)***
Ln $(hc)_t$	2.665	2.653	2.585	2.483
	(0.192)***	(0.210)***	(0.240)***	(0.274)***
Ln $(n + \delta)_t$	-0.365	-0.431	-0.397	-0.440
	(0.048)***	(0.094)***	(0.097)***	(0.105)***
Debt/GDP$_t$	---	0.002	-0.013	-0.014
		(0.002)	(0.012)	(0.012)
$(Debt/GDP_{t)})^2$	---	---	-0.004	-0.0003
			†(0.003)*	†(0.000)
Ln (x/m)	---	---	--	-0.050
				(0.053)
Diagnostics				
R^2	0.984	0.985	0.985	0.986
# of obs	21	21	21	21
Adj. D.F.	-3.252	-3.409	-3326	-3.395
	(-2.660)***	(-2.660)***	(-2.660)**	(-2.660)***
P.P.	-2.613	-3.062	-3.177	-3.111
	(-1.95)**	(-2.660)***	(-2.660)***	(-2.660)***

Robust standard error in parentheses * 10% statistical significance
**5% statistical significance
***1% statistical significance

6. Conclusion

A neoclassical growth model is developed under the assumption that debt and economic growth and capital accumulation for developing countries follow a non-linear process. Concavity in the capital accumulation process implies an optimal level of debt per GDP. We use a panel dataset of 10 developing countries to test for a long-run cointegration, a necessary condition for an error-correction model. However, a battery of unit root tests suggests that the variables in the structural models are not cointegrated of order (1,1).

Unit root tests of individual countries allows a subsample of developing countries consisting of Guatemala and Iceland are cointegrated of order (1,1). The cointegration equation corroborates a long run relationship among the traditional neoclassical growth model variables, including public debt ratios. The results indicate a concave relationship between debt and economic growth. Moreover, the subsample of countries suggests an optimal debt-to-GDP level of 8.75%. This outcome is inconsistent with the conclusions of other researchers in the literature who find higher levels. However, the error-correction model we cannot conclude that debt Granger causes economic growth in the long-run. We find no long-term relationship between debt levels and real gross physical capital. A similar analysis is conducted for each of the countries in the sub-sample. One of the countries, Iceland, has results consistent to that of the subsample. A long-run relation is determined but no long-run Granger causality of debt to GDP. The results suggest an 87.5%

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threshold level of debt. The results for Guatemala, the other country in the subsample, shows no long-run relationship, nor causality.

These near-robust results of nonlinearity are consistent with the findings of a host of researchers. Although formal conclusions cannot necessarily be concluded, but they support the concept of heterogeneity in debt effects on capital accumulation and economic growth of developing countries. This is a useful finding for public policy implementation.

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8. Appendix

A1 Unit Root – Tunisia

Tunisia Unit Root Tests				
	Aug. D.F. (Z_t)	DFGLS (τ)	Phillips-Perron (Z_t)	Order of Integration
Ln (rGDP)	-1.71	-1.63	-2.29	---
Δ Ln (rGDP)	-1.63	-2.03	-2.88**	---
Ln (INV)	-1.90	-1.57	-2.72	I(1)
Δ Ln (INV)	-3.80***	-4.43***	-4.66***	I(0)
Ln (debt/GDP)	-1.06	-1.38	-0.42	I(1)
Δ Ln (debt/GDP)	-1.70*	-1.83	-6.1***	I(0)
Ln (hc)	-1.79	-1.44	-0.66	I(0)
Δ Ln (hc)	-1.16	-1.81	-1.22	I(0)
Ln (n & delta)	-2.96***	-1.61	-1.95	I(1)
Δ Ln (n & delta)	-1.78**	-1.51	-2.64*	I(0)
Ln (physcap)	-1.48	-1.89	-1.53	I(1)
Δ Ln (physcap)	-1.90**	-2.13	-3.35**	I(0)
Ln (x/m)	-2.01**	-2.34	-2.85*	I(1)
Δ Ln (x/m)	-2.98***	-5.79***	-6.08***	I(0)

A 2 Unit Root Tests – Philippines

Philippines Unit Root Tests				
	Aug. D.F. (Z_t)	DFGLS (τ)	Phillips-Perron (Z_t)	Order of Integration
Ln (rGDP)	-1.03	-2.44	-0.46	---
Δ Ln (rGDP)	-1.57*	-2.11	-1.99	---
Ln (INV)	-2.33	-3.02	-2.42	I(1)
Δ Ln (INV)	-2.93***	-3.32*	-4.40***	I(0)
Ln (debt/GDP)	-2.16**	-1.62	-2.07	I(1)
Δ Ln (debt/GDP)	-2.80***	-3.56**	-5.17***	I(0)
Ln (hc)	-3.83***	-1.67	-13.33***	I(0)
Δ Ln (hc)	-1.01	-3.25*	-0.96	---
Ln (n & delta)	-0.04	-1.01	0.15	I(1)
Δ Ln (n & delta)	-2.06**	-2.71	-2.94*	I(0)
Ln (physcap)	-0.06	-1.89	-1.53	---
Δ Ln (physcap)	-1.90**	-2.65	-1.62	---
Ln (x/m)	-1.62*	-2.70	-1.72	I(1)
Δ Ln (x/m)	-2.10**	-4.11***	-2.84*	I(0)

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A3 Unit Root Tests – Mauritius

Mauritius Unit Root Tests				
	Aug. D.F. (Z_t)	DFGLS (τ)	Phillips-perron (Z_t)	Order of Integration
Ln (rGDP)	-1.36	-1.52	-2.03	I(1)
Δ Ln (rGDP)	-1.89**	-2.13	-3.65**	I(0)
Ln (INV)	-2.18**	-2.66	-1.79	I(1)
Δ Ln (INV)	-4.34***	-4.16***	-6.45***	I(0)
Ln (debt/GDP)	-1.40*	-2.38	-1.46	I(1)
Δ Ln (debt/GDP)	-2.64***	-3.29*	-3.97***	I(0)
Ln (hc)	-1.82**	-2.02	-5.54***	I(0)
Δ Ln (hc)	-1.05	-1.90	-1.05	---
Ln (n & delta)	0.25	-0.94	0.95	I(1)
Δ Ln (n & delta)	-3.16***	-2.02	-4.00***	I(0)
Ln (physcap)	-0.87	-2.52	-1.17	---
Δ Ln (physcap)	-1.68*	-1.70	-1.80	---
Ln (x/m)	-0.20	-1.37	-0.79	I(1)
Δ Ln (x/m)	-1.99**	-2.85	-3.67***	I(0)

A4 Unit Roots Tests -- Maldives

Maldives Unit Root Tests				
	Aug. D.F. (Z_t)	DFGLS (τ)	Phillips-Perron (Z_t)	Order of Integration
Ln (rGDP)	-0.73	-2.63	-0.64	I(1)
Δ Ln (rGDP)	-3.31***	-3.87***	-5.11**	I(0)
Ln (INV)	-0.94	-2.21	-2.03	I(1)
Δ Ln (INV)	-3.60***	-3.87***	-7.41***	I(0)
Ln (debt/GDP)	-1.41*	-1.33	-1.27	I(1)
Δ Ln (debt/GDP)	-1.67*	-2.70	-3.83***	I(0)
Ln (hc)	-1.28	-1.65	-0.45	I(0)
Δ Ln (hc)	-0.38	-2.15	-0.41	---
Ln (n & delta)	-2.27**	-2.55	-1,75	---
Δ Ln (n & delta)	-2.55**	-2.30	-2.17	I(0)
Ln (physcap)	-1.65*	-1.66	-2.60	---
Δ Ln (physcap)	-1.63*	-2.77	-1.62	---
Ln (x/m)	-0.04	-1.27	-0.71	I(1)
Δ Ln (x/m)	-1.85**	-2.22	-3.67**	I(0)

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A5 Unit Root Tests -- Jordan

Jordan Unit Root Tests				
	Aug. D.F. (Z_t)	DFGLS (τ)	Phillips-Perron (Z_t)	Order of Integration
Ln (rGDP)	-1.81**	-2.76	-1.25	I(1)
Δ Ln (rGDP)	-2.01**	-3.06	-2.71*	I(0)
Ln (INV)	-4.19***	-2.79	-1.59	I(1)
Δ Ln (INV)	-3.47***	-2.47	-2.91*	I(0)
Ln (debt/GDP)	-1.43*	-1.80	-1.13	I(1)
Δ Ln (debt/GDP)	-2.39**	-2.55	-3.97***	I(0)
Ln (hc)	0.65	-1.95	-3.18**	I(0)
Δ Ln (hc)	-1.62*	-1.70	-1.43	---
Ln (n & delta)	-1.78**	-2.72	-1.31	I(1)
Δ Ln (n & delta)	-2.45**	-2.17	-3.22**	I(0)
Ln (physcap)	1.94	-3.12*	-1.26	I(1)
Δ Ln (physcap)	-2.07*	-6.38***	-4.16***	I(0)
Ln (x/m)	-2.65***	-2.77	-1.97	I(1)
Δ Ln (x/m)	-3.30***	-2.80	-3.16**	I(0)

A6 Unit Root Tests -- India

India Unit Root Tests				
	Aug. D.F. (Z_t)	DFGLS (τ)	Phillips-Perron) (Z_t	Order of Integration
Ln (rGDP)	1.72	-0.99	4.43	---
Δ Ln (rGDP)	-0.86	-2.36	-2.73*	I(0)
Ln (INV)	-0.36	-1.71	-0.31	I(1)
Δ Ln (INV)	-2.51**	-3.27*	-6.57***	I(0)
Ln (debt/GDP)	-1.52*	-1.51	-1.23	I(1)
Δ Ln (debt/GDP)	-1.49*	-2.28	-3.07**	I(0)
Ln (hc)	-1.65	-2.33	-2.00	I(0)
Δ Ln (hc)	-1.73*	-1.96	-1.58	---
Ln (n & delta)	-1.58*	-1.61	-1.71	I(1)
Δ Ln (n & delta)	-2.72***	-2.71	-4.72***	I(0)
Ln (physcap)	2.68	-1.11	5.21	I(1)
Δ Ln (physcap)	-0.78*	-3.53**	-1.1.8	I(0)
Ln (x/m)	-0.94	-1.97	-0.44	I(1)
Δ Ln (x/m)	-2.95***	-2.13	-5.77***	I(0)

A7 Unit Root Tests -- Iceland

Iceland Unit Root Tests				
	Aug. D.F. (Z_t)	DFGLS (τ)	Phillips-perron (Z_t)	Order of Integration
Ln (rGDP)	-1.81**	-2.76	-1.25	I(1)
Δ Ln (rGDP)	-2.01**	-3.06	-2.71*	I(0)
Ln (INV)	-4.19***	-2.79	-1.59	I(1)
Δ Ln (INV)	-3.47***	-2.47	-2.91*	I(0)
Ln (debt/GDP)	-1.43	-1.80	-1.13	I(1)
Δ Ln (debt/GDP)	-2.39*	-2.55	-3.97***	I(0)
Ln (hc)	0.65	-1.95	-3.18	---
Δ Ln (hc)	-1.62*	-1.70	-1.43	---
Ln (n & delta)	-1.78*	-2.72	-1.31	I(1)
Δ Ln (n & delta)	-2.45**	-2.17	-3.22**	I(0)
Ln (physcap)	1.94	-3.12*	-1.26	I(1)
Δ Ln (physcap)	-2.07**	-6.38***	-4.16***	I(0)
Ln (x/m)	-2.65***	-2.77	-1.97	I(1)
Δ Ln (x/m)	-3.30***	-2.80	-3.16**	I(0)

A8 Unit Root Tests -- Guatemala

	Guatemala Unit Root Tests			
	Aug. D.F. (Z_t)	DFGLS (τ)	Phillips-Perron (Z_t)	Order of Integration
Ln (rGDP)	-0.12	-1.88	0.52	I(1)
Δ Ln (rGDP)	-2.38**	-3.00	-4.16***	I(0)
Ln (INV)	-1.23	-2.82	-2.47	I(1)
Δ Ln (INV)	-2.65***	-3.77***	-3.37**	I(0)
Ln (debt/GDP)	-1.26	-1.67	-1.41	I(1)
Δ Ln (debt/GDP)	-2.36**	-1.89	-3.71**	I(0)
Ln (hc)	-0.22	-2.94	-0.10	---
Δ Ln (hc)	-2.06**	-1.95	-1.94	---
Ln (n & delta)	-0.15	-2.14	-0.12	I(1)
Δ Ln (n & delta)	-2.48**	-3.27*	-3.85***	I(0)
Ln (physcap)	0.99	-1.63	1.79	I(1)
Δ Ln (physcap)	-2.39**	-2.65	-2.86*	I(0)
Ln (x/m)	-1.76**	-1.52	-2.78*	I(1)
Δ Ln (x/m)	-3.20***	-3.49**	-6.60***	I(0)

A9 Unit Root Tests -- Thailand

	Thailand Unit Root Tests			
	Aug. D.F. (Z_t)	DFGLS (τ)	Phillips-Perron (Z_t)	Order of Integration
Ln (rGDP)	-0.37	-2.60	-0.78	---
Δ Ln (rGDP)	-1.60*	-2.86	-2.35	---
Ln (INV)	-1.53*	-2.31	-1.49	I(1)
Δ Ln (INV)	-2.37**	-2.92	-3.69**	I(0)
Ln (debt/GDP)	-1.22	-0.10	-1.22	---
Δ Ln (debt/GDP)	-2.20	-1.38*	-2.20	---
Ln (hc)	-0.10	-2.47	-3.78	---
Δ Ln (hc)	-1.38*	-1.49	-1.41	---
Ln (n & delta)	-1.16	-3.35*	-1.53	I(1)
Δ Ln (n & delta)	-2.50**	-3.32*	-2.50	I(0)
Ln (physcap)	-1.67	-3.25	-2.47	---
Δ Ln (physcap)	-1.98**	-1.79	-1.67	---
Ln (x/m)	-1.74	-2.13	-2.15*	I(1)
Δ Ln (x/m)	-2.50**	-4.05***	-4.09***	I(0)

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A10 Unit Root Tests -- Singapore

	Singapore Unit Root Tests			
	Aug. D.F. (Z_t)	DFGLS (τ)	Phillips-Perron (Z_t)	Order of Integration
Ln (rGDP)	-0.85	-3.06*	-0.53	I(1)
Δ Ln (rGDP)	-3.03***	-3.99***	-5.02***	I(0)
Ln (INV)	-1.23	-1.41	-1.37	I(1)
Δ Ln (INV)	-2.67***	-3.23*	-5.69***	I(0)
Ln (debt/GDP)	-0.77	-3.14	-1.28	I(1)
Δ Ln (debt/GDP)	-2.18**	-4.09***	-3.36**	I(0)
Ln (hc)	-0.36	-2.86	-1.18	---
Δ Ln (hc)	-1.58*	-1.42	-1.57	---
Ln (n & delta)	-1.03	-3.22*	-1.03	---
Δ Ln (n & delta)	-2.46**	-2.93	-2.30	---
Ln (physcap)	0.26	-2.19	-1.09	---
Δ Ln (physcap)	-2.27**	-2.56	-2.38	---
Ln (x/m)	-1.23	-1.71	-1.33	I(1)
Δ Ln (x/m)	-3.27***	-3.81***	-6.39***	I(0)

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