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# The Impact of Infrastructure on Economic Growth in Botswana

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## BIDPA

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# ABSTRACT

The study determines the impact of infrastructure on economic growth in Botswana. The study employs an Autoregressive Distributed Lag (ARDL) estimation technique to determine how infrastructure affects economic growth in Botswana. The empirical results show that healthcare infrastructure has a positive and significant impact on economic growth in Botswana in the long run. The results further reveal that electric power consumption has a positive and significant effect in influencing economic growth in the short run. The results imply that in order to achieve higher economic growth, policymakers should consider accelerating improvement of healthcare infrastructure.

**Keywords:** Economic Growth, Infrastructure, Co-integration, Error Correction Model, ARDL

**JEL Classification**: C22, H54

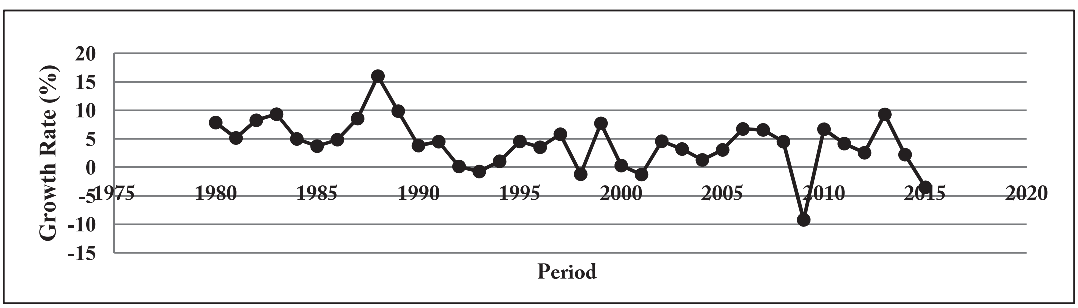
# 1. INTRODUCTION AND BACKGROUND

Infrastructure development plays an important role in a country's economic growth. It is considered an effective tool to promote economic growth and competitiveness. The World Bank (1994) asserts that provision of infrastructure in their right quantity and quality determines the success or failure of a country in the areas of diversification of production, trade expansion and reduction of poverty amongst others. Infrastructure development therefore, plays a key role in determining the growth and performance of a country's economy. As such, many countries across the world have invested and continue to invest in infrastructure development.

Infrastructure development is a priority for any economy. It is every country's desire to attain the highest level of infrastructure development. The Government of Botswana recognises the importance of efficient provision of public infrastructure and utilities to support competitiveness and productivity. This has been key to Botswana's national objectives since independence. When the country gained independence in 1966, it was the world's third-poorest country, with relatively low level of infrastructure. However, the discovery of diamonds in 1965 was the turning point for the country. The government used mining revenues to invest in infrastructure, healthcare, and education.

Botswana has recorded impressive annual gross domestic product (GDP) growth rates since independence. The country's annual real GDP growth rates have been remarkable having recorded the highest annual GDP growth rate of 16 percent in 1988 (Figure 1). The country recorded the record low annual GDP growth rate of -9 percent in 2009 as a result of the global financial crisis. On average, Botswana annual GDP growth grew at around 4 percent per annum.

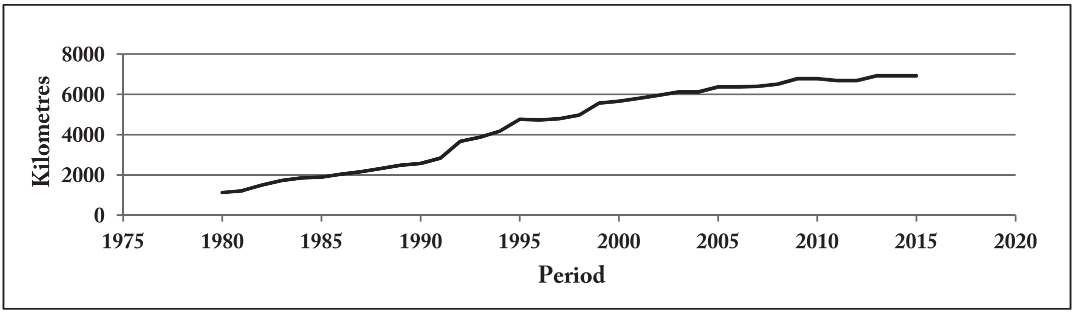
**Figure 1:Annual Real GDP Growth Rate; 1980-2015**




Source: World Development Indicators (2016)

Botswana has prudently used mineral revenues to drive the country's development agenda particularly the development of infrastructure. The country has made significant infrastructure progress in recent years, spanning the transport, water and sanitation, power, and mobile telephony sectors. Government has invested heavily on the construction and maintenance of the tarred roads since independence. The increasing trend of the length of tarred roads maintained by the central government is indicative of government's continued investment in transport infrastructure particularly road transport which is the most commonly used mode of transport in the country (Figure 2).

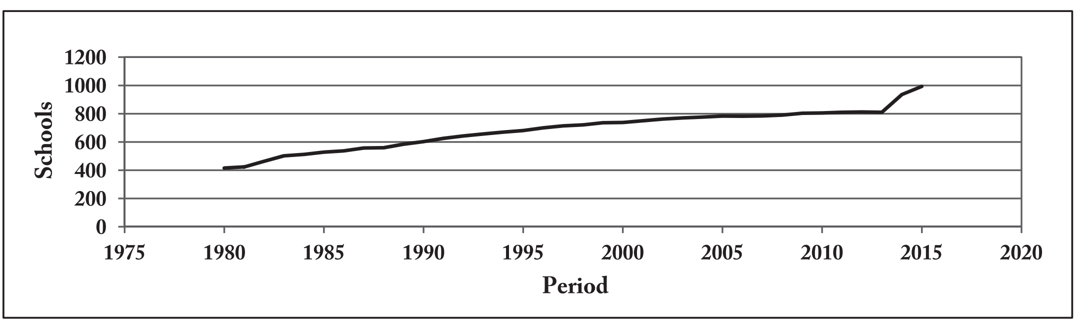
**Figure 2: Length of Tarred Roads Maintained by the Central Government**




Source: Statistics Botswana (2016)

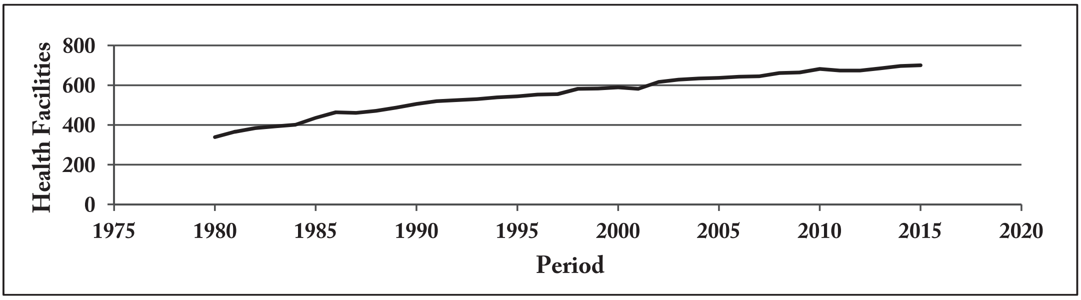
The Government of Botswana has also invested heavily on the construction of public schools (primary and secondary). In 1980, there were 415 schools in the country. By 2015, the number of schools established had grown more than double with the total number of schools standing at 993 (Figure 3). This shows the country's commitment to attaining higher level of human capital development. The same growing trend is seen on the number of health facilities established. In 1980, there were 339 health facilities in the country and by 2015 there were 700 health facilities (Figure 4). These include hospitals, clinics and health posts.

**Figure 3: School Establishment; 1980-2015**




Source: Statistics Botswana (2016)

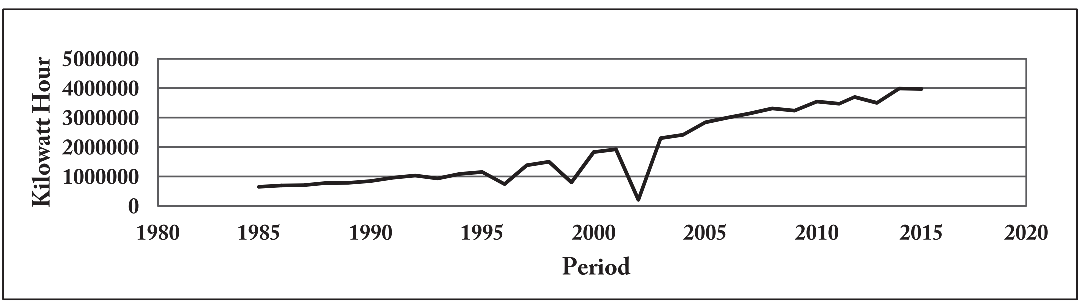
**Figure 4: Health Facilities; 1980-2015**




Source: Statistics Botswana (2016)

Between the years 1980 and 2015, electricity distribution in the country has been on the rising trend, although there were periods of serious power shortages; the most recent being the 2008 power crisis (Figure 5). The full operation of the 600 megawatt Morupule B power station in 2016 contributed to the stabilization of electricity supply in the country. The upward trend is a result of the government's effort in generating electricity locally as well as importing from neighbouring South Africa. The Ministry of Mineral Resources, Green Technology and Energy Security formerly the Ministry of Minerals, Energy and Water Resources has received a larger share of the development budget in recent years. The major development projects are for electricity generation and transmission.

**Figure 5: Electricity Distribution in Kilo Watt Hour (KWH) from 1985-2015**




Source: Statistics Botswana (2016)

Clearly, Botswana has made some significant progress in terms of infrastructure development in recent years. Notwithstanding this, the country is still faced with several infrastructure challenges some of which include a sizeable investment on maintenance and upgrading of existing infrastructure such as roads. Good infrastructure is an important variable towards improving productivity and competitiveness which ultimately lead to increased economic growth. Aschauer (1989), and DeLong and Summers (1991) argue that specific types of investment, such as public infrastructure and machinery and equipment, have a strong association with productivity and growth. Thus, the optimal allocation of investment funds to sector-specific infrastructures is an important policy issue (Madden and Savage, 1998). This paper therefore, seeks to determine how infrastructure stock impacts long term economic growth in Botswana.

The rest of the paper is organised as follows. Section 2 reviews the literature on the impact of infrastructure on economic growth. Section 3 lays out the theoretical framework. Section 4 sets out the econometric methodology used while section 5 discusses the empirical results. Section 6 concludes the paper and highlights policy implications of the results.

## 2. LITERATURE REVIEW

There is extensive literature on the impact of infrastructure on long-run economic growth. However, a vast array of empirical literature on infrastructure and its link to economic performance has adopted various estimation methodologies on a variety of data (panel and time series data) and measures of infrastructure (Loayza and Odawara, 2010). The vast majority of the studies find a positive impact on the relationship between infrastructure and output, growth, or productivity. Loayza and Odawara (2010) posit that the results largely depend on the measures of infrastructure employed in the analysis. Various measures of infrastructure such as physical units of infrastructure, stocks of public capital, and infrastructure spending flows have been used to examine the impact of infrastructure on growth.

Straub (2008) asserts that the positive effect of infrastructure on growth is often obtained when physical indicators of infrastructure are used. However, the results are not so clear when infrastructure spending flows are used as proxies for infrastructure. This may be attributed to the fact that political and institutional factors (such as inefficient government) and not the level of infrastructure investment often affect the level of infrastructure stocks and the quality of services in different infrastructure sectors, particularly in developing countries (Loayza and Odawara, 2010).

Aschauer (1989, 1990) found a significant positive relationship between per capita income and density of paved roads using a time series and cross section data from 58 states. Esfahani and Ramirez (2003) applied a cross-country regression over the period of 1965-1995 to a structural model of infrastructure and growth. The empirical findings of the study showed that the contribution of infrastructure services to economic growth is substantial and it exceeds the cost of the provision of those services.

Easterly and Rebelo (1993) in a study on the growth impact of government spending found that public expenditure on transport and communications significantly raises growth. Sanchez-Robles (1998) also found that measures of physical infrastructure are positively and significantly related to growth in GDP per capita. Easterly (2001) concludes that a measure of telephone density contributes significantly to the growth performance of developing countries.

Canning and Pedroni (2004) in the study on the effect of infrastructure on long run economic growth found that those countries which had developed their infrastructure over time had better economic condition as compared to those who did not consider infrastructure development as a path of economic development. They argue that infrastructure, especially telecommunication, electricity growth and energy growth, paved roads, basic health and educational facility have direct impact on the country's economic development and also improved the income level of the common people.

Calderon and Serven (2008) used panel data from 1960 to 2005 to analyse the impact of infrastructure on economic performance of African countries. They employed growth regressions estimated through a Generalized Method of Moments estimator and evaluated the impact of several types of infrastructure assets, as well as measures of quality of their services. They established that both infrastructure stock and quality are positively and significantly related to real GDP per capita growth.

Straub and Hagiwara (2011) applied growth regressions and growth accounting technique to analyse the link between infrastructure, growth and productivity in developing Asian countries. The study findings showed that infrastructure development has direct and positive impact on different sectors of the economy. Haider et al. (2012) used annual time series data from 1972 to 2009 to determine the impact of infrastructure on economic growth of Pakistan. They concluded that there exist a statistically significant and positive relationship between infrastructure development and economic growth.

A study by Srinivasu and Rao (2013) on the relationship between infrastructure development and economic growth established that there was a positive and statistically significant relationship between infrastructure development and economic growth, as well as infrastructure development and poverty. According to the study, improvement in infrastructure leads to an increase in productivity in the production process and ultimately improvement in economic growth.

There are few quantitative studies on the impact of infrastructure on economic growth in Botswana. However, these studies either use only one or two infrastructure variables in determining the impact of infrastructure on economic growth. For example, Adebola (2011) investigates the relationship between electricity consumption and real gross domestic product in Botswana for the period 1980-2008. The study established a unidirectional causality from electricity consumption to real gross domestic product.

Mbulawa (2017) in a similar study to the current study examined the impact of economic infrastructure on long term economic growth in Botswana. Using annual time series data for the period 1985 to 2015, the study employed a vector error correction model (VECM) and the ordinary least squares (OLS) technique to determine the impact of electricity distribution and maintenance of roads on long term economic growth in Botswana. The study findings show that long term economic growth is explained by both measures of infrastructure (electricity distribution and maintenance of roads). However, electricity distribution was found to have a greater impact on economic growth than road maintenance.

This study differs from the previous studies in that it uses the autoregressive distributed lag (ARDL) model to determine the impact of infrastructure on economic growth in Botswana. ARDL is the preferred estimation technique because unlike the residual based tests such as Engle-Granger (1987) and the maximum likelihood based test such as Johansen (1991 and 1995) for testing the long-run association, the ARDL approach does not require that the underlying series included in the system have same order of integration. Another advantage of this approach is that the model takes sufficient number of lags to reduce the intensity of serial correlation of residuals in a general to specific modeling framework.

Also, a dynamic error correction model (ECM) can be derived from ARDL through simple linear transformation. Also, an appropriate specification of the ARDL equation helps to fix the problems of endogenous variables and residual serial correlation. In addition, it performs better than Engle-Granger (1987) and Johansen (1990 and 1995) cointegration tests in the case of small samples. Lastly, the current study differs from the previous studies as it considers additional measures of infrastructure such as healthcare infrastructure and education infrastructure

# 3. THEORETICAL FRAMEWORK

To analyse the impact of infrastructure on economic growth, the study explores how production function growth theories factor in infrastructure as a component that influences output and eventually overall economic growth. The study focuses on two prominent growth theories; the neoclassical growth theory also known as the Solow-Swan growth model and the endogenous growth theory.

## 3.1 EXOGENOUS GROWTH THEORY

### *3.1.1 Neoclassical Growth Model*

The neoclassical growth model or the Solow growth model is an extension of the Harrod - Domar (1946) growth model which recognise capital stock as the only factor of production. Solow and Swan (1956) modified the Harrod -Domar Model to include labour as a factor of production. The neoclassical model assumes capital is subject to diminishing returns to scale. The model can be summarized as follows,

$$Y(t) = f\left[K_t^{\alpha}\left(A_t L_t\right)\right]^{\beta} \qquad (1)$$

where output $Y(t)$ is produced from capital stock $K(t)$ and augmented labour $A(t)L(t)$, $\alpha+\beta=1$ depicting constant returns to scale.

The neoclassical growth theory states that in the short-run, the rate of economic growth is influenced by capital accumulation as determined by the saving and depreciation rates. The theory further assumes that in the long-run, economic growth is exogenously determined by population growth rate and technological progress growth rate.

An important prediction of this model is international convergence in output levels: as poor countries are assumed to grow faster than rich countries. Another prediction is that when capital is mobile, advanced economies should invest in poor countries where capital is scarce and the marginal returns to investment are high.

Based on the neoclassical growth model assumption that long run growth is influenced by technological progress and labour force growth due to population change, shocks in infrastructure stock can only have temporary effects on income. Thus, shocks to infrastructure can raise the steady-state income per capita in an endogenous growth model.

Social capital and human capital are also important determinants of economic growth (Lucas, 1988; Barro, 1991). Higher public expenditure on social infrastructure induces more literacy, better health and skills, which lead to higher productivity and growth (Sahoo et al. 2010).

## 3.2 ENDOGENOUS GROWTH THEORY

The endogenous growth theory came as a reaction to omissions and deficiencies in the Solow- Swan neoclassical growth model. It is a new theory which explains the long run growth rate of an economy on the basis of endogenous factors as against exogenous factors of the neoclassical growth theory. The endogenous growth model developed by Romer (1986) and Lucas (1988) focused on the role of human capital as a main source of increasing returns and divergence in growth rates between developed and underdeveloped countries The endogenous growth theory states that investment in human capital, innovation and knowledge are significant contributors to economic growth. Thus, economic growth is determined by endogenous and not external factors. The theory also highlights the importance of positive externalities and spill over effects as well as policy measures in determining economic growth in the long run.

### *3.2.2 The AK Model*

This is the simplest endogenous growth model. It is an extension of the Solow model. The model is defined as follows,

$$Y = AK^{\alpha} L^{\beta} \tag{2}$$

where $Y$ is national output, $K$ is the capital stock and $A$ is a constant on assumption of constant returns to scale (CRS). The CRS replaces the assumption of diminishing returns to scale in neoclassical growth theory, so that investment matters for long run growth and growth is endogenous (Hussien and Thirwall, 2000).

The new growth theory, such as the first model in Lucas (1988), endogenizes the technology factor as follows,

$$A_t = BH^c, \qquad 0 < c < 1 \tag{3}$$

where $H$, is the level of human capital stock. If $H$ increases by 1 percent, $A$ , is assumed to increase by $c$ percent.

Supposing that labor input is allocated between physical output production and human capital production by $xL$, and $(1-x)L$, respectively. Then the production function of equation (2) can be respecified as,

$$Y = B\left[K^{\alpha} H^{c} (xL)^{\beta}\right] \tag{4}$$

According to this model, endogenous growth is possible as long as there is continuous investment in human capital even if it keeps being accumulated. Model (4) introduces a key assumption that there are no diminishing returns in the production of human capital.

Endogenous growth model assumes that the growth rate of the economy depends positively on the savings/investment rate, implying that any public policy measure that increases the savings rate accelerates economic growth permanently. The model implies divergence in international income. If two economies start out with different initial stocks of capital, then the absolute gap gets larger as time proceeds. If two economies have different savings rates and hence different growth rate, the ratio of international income level explodes (collapses).

The theoretical review reveals that both the endogenous and exogenous growth theories do not explicitly specify the role of infrastructure capital in the production process, whether it represent an additional input factor in the production function or influence the technology with which other inputs are combined. The role of infrastructure is implied on the premise of the underlying assumptions of the growth theories. Infrastructure investments feature temporary growth effects in the presence of diminishing returns to capital under exogenous theory, while under the endogenous theory they improve the efficiency of all other input factors and hence long-run productivity growth.

# 4. METHODOLOGY

## 4.1 MODEL SPECIFICATION

In order to assess the impact of infrastructure on growth, we consider different measures of infrastructure which include; electric power consumption, total length of roads maintained by central government, the number of health facilities and schools established as proxies for healthcare infrastructure and education infrastructure respectively. As such, the following equation is used to empirically examine the impact of infrastructure stock on output in Botswana.

$$\ln GDPPC_t = \partial_0 + \beta_1 \ln HEF_t + \beta_2 \ln SCE_t + \beta_3 \ln EPC_t + \beta_4 \ln TAR_t + \beta_5 \ln TO_t + \beta_6 RIR_t + \varepsilon_t \quad (5)$$

where GDPPC, HEF, SCE, EPC, TAR, TO and RIR denote GDP per capita, the number of health facilities, the number of schools established, electric power consumption, total length of roads maintained by central government, trade openness and the lending real interest rate respectively. The study uses the number of health facilities and school establishment as proxies for healthcare infrastructure and education infrastructure respectively.

## 4.2 DATA SOURCES

The study employs annual time series data for Botswana for the period 1980 to 2015. The choice of the sample period is informed by data availability. The main data source for this study is Statistics Botswana. Data on electric power consumption (measured in kWh per capita) and trade openness was obtained from the World Bank Development Indicators (2017). All variables except for the real interest rate are expressed in logarithm form.

## 4.3 ECONOMETRIC ANALYSIS

Several empirical studies on the impact of infrastructure on output growth often come across the problem of endogeneity (Sahoo et al., 2010). The underlying argument is whether infrastructure development leads to increases in productivity, efficiency and competitiveness and thereby output growth or output growth necessitates overall infrastructure development. Given this reserve causality and possibility of more than one endogenous variable, the Autoregressive-distributed lag model (ARDL) developed by

Pesaran et al. (2001) is the most suitable model to evaluate the impact of infrastructure on output growth. This is because in the ARDL model, each of the underlying variables stands as a single equation, therefore, endogeneity is less of a problem in the ARDL technique because it is free of residual correlation as all variables are assumed endogenous. The error correction version of the ARDL model of Equation (5) is formulated as follows,

$$\Delta\ln(GDPPC_t)=\partial_0+\sum_{i=1}^{n_1}\alpha_{1i}\Delta\ln(GDPPC_{t-i})+\sum_{i=1}^{n_2}\alpha_{2i}\Delta\ln(HEF_{t-i})+\sum_{i=1}^{n_3}\alpha_{3i}\Delta\ln(SCE_{t-i})+\sum_{i=1}^{n_4}\alpha_{4i}\Delta\ln(EPC_{t-i})$$
$$+\sum_{i=1}^{n_5}\alpha_{5i}\Delta\ln(TAR_{t-i})+\sum_{i=1}^{n_6}\alpha_{6i}\Delta\ln(TO_{t-i})+\sum_{i=1}^{n_7}\alpha_{7i}\Delta RIR_{t-i}+\beta_1\ln(GDPPC_{t-1})+\beta_2\ln(HEF_{t-1})+\beta_3\ln(SCE_{t-1})$$
$$+\beta_4\ln(EPC_{t-1})+\beta_5\ln(TAR_{t-1})+\beta_6\ln(TO_{t-1})+\beta_7 RIR_{t-1}+\varepsilon_t \quad (6)$$

where $\partial_0$ is a constant, $\Delta$ represent the first difference, $\alpha_i's$ depict the short run dynamics of the model, $\beta_i's$ show the long association while t, ε, n1,....n7 represent the time period, the error term and the optimal lag lengths, respectively. All other variables are as previously defined.

### *4.3.1 ARDL Bounds Test and Cointegration*

The ARDL bounds testing approach tests the existence of long run relationship among the variables by conducting an F-test for the joint significance of the coefficients of the lagged levels of the variables. It tests the null hypothesis:

$$H_0:\beta_1=\beta_2=\beta_3=\beta_4=\beta_5=\beta_6=\beta_7=0$$

against the alternative hypothesis:

$$H_1:\beta_1\neq\beta_2\neq\beta_3\neq\beta_4\neq\beta_5\neq\beta_6\neq\beta_7\neq0$$

Rejection of $H_0$ implies that the variables have a long-run relationship. Pesaran et al., (2001) provide bounds on the critical values for the asymptotic distribution of the F-statistic. If the computed F-statistic falls below the lower bound, there is no co-integration. If the F-statistic exceeds the upper bound, we conclude that there is co-integration. Lastly, if the F-statistic falls between the bounds, the test is inconclusive.

## 5. EMPIRICAL RESULTS

### 5.1 UNIT ROOT TEST

The Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) unit root tests are employed to assess the stationary behaviour of the selected variables. It is important to conduct unit root tests in order to determine the appropriate model to use in assessing the impact of infrastructure on economic growth. Table 1A and Table 2A report the results of the ADF and PP unit root test respectively. The results show that all the variables are stationary at levels except for trade openness (TO) which becomes stationary at first difference.

The ARDL model is the appropriate model to estimate the impact of infrastructure on economic growth since the variables selected are a combination of I(0) and I(1). One of the advantages of the ARDL estimation technique is that it can be applied regardless of whether the underlying regressors are I(1) or I(0) or a combination of both (Pesaran and Shin, 1999). Secondly, it is more robust and performs better in small sample sizes making it superior to multivariate cointegration, and very appropriate in the current analysis. Third, ARDL approach generally provides unbiased estimates and valid t-statistics even when some of the regressors are endogenous (Pesaran et al, 2001).

### 5.2 LAG LENGTH SELECTION CRITERIA

ARDL bound testing approach to long run level relationship among the variables requires the determination of the optimal lag for the cointegrating equation based on the assumption of serially uncorrelated residual. The lag length that minimizes the value of the AIC, SC, HQ and SBC and at which the model does not have autocorrelation is the optimal lag. The Schwarz Information Criterion (SC) was used to select the optimal lag length. Based on the SIC, it was found that one lag was optimal. SC was used for model selection such as determining the lag length of a model, with smaller values of the information criterion being preferred. This is shown in the below Table 3A.

### 5.3 F-BOUNDS TEST

The F-bounds test results are presented in Table 1. The calculated F-statistics (7.032) is greater than the lower and upper bound critical values at the 1, 5 and 10 percent level of significance. This implies that there is a cointegrating relationship between GDP per capita and the explanatory variables (the number of health facilities, school establishment, trade openness, electric power consumption, total length of roads maintained by central government and the real interest rate). Since the F-bounds test results lead to the conclusion that there is a long run relationship among the variables in our model, the marginal impacts of the number of health facilities, number of schools established, electric power consumption, total length of roads maintained by central government, trade openness and the lending real interest rate on economic growth is examined by estimating the short-run (ECM) and long-run coefficients of the ARDL (1,1,1,1,0,0,0) model.

**Table 1: F-Bounds Test Results**

| Critical Value | | |
|---|---|---|
| **Pesaran et al., (2001)** | **Lower Bound Value** | **Upper Bound Value** |
| 1% | 3.15 | 4.43 |
| 5% | 2.45 | 3.61 |
| 10% | 2.12 | 3.23 |
| Calculated F-statistics = 7.032 k=6 | | |

## 5.4 LONG RUN ESTIMATION

The long-run estimation results are presented in Table 2. The results show that, in the long run, the number of health facilities has a positive and significant impact on GDP per capita (economic growth) such that a one percent increase in the number of health facilities will lead to approximately 0.108 percent increase in GDP per capita. The result also shows that, in the long run, a one percent increase in trade openness will lead to approximately 0.323 percent increase in GDP per capita. However, the number of schools established, electric power consumption, maintenance of road infrastructure and the lending real interest rate do not have significant impact on GDP per capita in the long run.

**Table 2: Long Run Estimation Results**

| Variable | Coefficient | Std. Error | t-Statistic | P-Value |
|---|---|---|---|---|
| HEF | 0.108 | 0.054 | 1.975 | 0.059*** |
| SCE | -0.050 | 0.033 | -1.513 | 0.143 |
| EPC | -0.010 | 0.007 | -1.317 | 0.200 |
| TAR | 0.087 | 2.072 | 0.042 | 0.966 |
| TO | 0.323 | 0.102 | 3.168 | 0.004** |
| RIR | 0.141 | 0.134 | 1.055 | 0.301 |
| C | -39.025 | 18.008 | -2.167 | 0.040 |
| Adjusted R-squared | 0.702 | | | |

Note; *, **, *** indicate statistical significance at 1%, 5% and 10% respectively.

## 5.5 SHORT RUN ESTIMATION

The result of the estimation of the short-run coefficient from the error correction model (ECM) version of the selected ARDL (1,1,1,1,0,0,0) model are presented in Table 3. The results show that the estimated coefficient of first period lag of electric power consumption has a positive and significant relationship with GDP per capita in the short run such that a one percent increase in electric power consumption leads to approximately 0.019 percent increase in GDP per capita. This finding is in line with the findings of Mbulawa (2017) and Esen and Bayrak (2017). Energy consumption contributes more to economic growth as the import dependence of the country decreases.

The results further show that trade openness has a significant and positive effect on GDP capita in the short run such that a 1 percent increase in trade openness spurs economic growth by approximately 0.302 percent. This finding is in accordance with the findings of Romer (1994), Coe and Helpman (1995) and Grossman and Helpman (1991). Interestingly, school establishment which is proxy for education infrastructure is statistically significant and has a negative impact on economic growth. This finding is inconsistent with economic theory as physical capital investment in education has a positive impact on economic growth. However, this finding may be due to longer time interaction of education infrastructure to economic growth.

The results further show that the number of health facilities, maintenance of road infrastructure and the lending real interest rate do not have significant impact on GDP per capita in the short run. In addition, the coefficient of the lagged error correction term (ECT(-1)) has the correct sign (negative) and statistically significant. This ensures that long run equilibrium is restored after a shock. The coefficient of the ECT (-0.936) implies that about 94 percent of any deviation from the previous year's shock converge back to the long run equilibrium in the current year. The adjusted R-Squared value of 0.594 implies that the model explains about 59 percent of the variation in GDP per capita.

**Table 3: Short Run Estimation Results**

| Variable | Coefficient | Std. Error | t-Statistic | P-Value |
|---|---|---|---|---|
| GDPG(-1) | 0.063 | 0.164 | 0.386 | 0.702 |
| HEF | 0.017 | 0.067 | 0.264 | 0.793 |
| HEF(-1) | 0.083 | 0.065 | 1.263 | 0.218 |
| SCE | -0.117 | 0.038 | -3.079 | 0.005* |
| SCE(-1) | 0.069 | 0.054 | 1.287 | 0.210 |
| EPC | -0.028 | 0.008 | -3.288 | 0.003 |
| EPC(-1) | 0.019 | 0.008 | 2.177 | 0.039** |
| TAR | 0.082 | 1.940 | 0.042 | 0.966 |
| TO | 0.302 | 0.083 | 3.622 | 0.001* |
| RIR | 0.132 | 0.118 | 1.119 | 0.274 |
| ECT(-1) | -0.936 | 0.119 | -7.844 | 0.000 |
| Adjusted R-squared | 0.594 | | | |

Note; *, **, *** indicate statistical significance at 1%, 5% and 10% respectively.

### 5.6 DIAGNOSTIC TESTS

Diagnostic tests are performed on the estimated short run model to ensure that none of the assumptions of Ordinary Least Square (OLS) are be violated. The study tests for serial correlation, heteroscedasticity, specification form and normal distribution of the estimated model. The results of the short run diagnostic tests are provided in Table 4A.

The results show that the estimated model passes all diagnostic tests hence there is absence of autocorrelation and heteroscedasticity in the model and it is also normally distributed and correctly specified.

## 6. CONCLUSIONS AND POLICY IMPLICATIONS

This paper determined how infrastructure stock impacts long-term economic growth in Botswana using the ARDL framework. The infrastructure variables considered in the study are the number of health facilities (proxy for healthcare infrastructure), number of schools established (proxy for education infrastructure), electric power consumption and the total length of roads maintained by central government. The results of the long run estimation show that only healthcare infrastructure has a positive and significant impact on GDP per capita in Botswana which implies that healthcare infrastructure plays an important role in driving economic growth in Botswana. However, the results reveal that the number of schools established, electric power consumption and the total length of roads maintained by central government do not have a significant impact on GDP per capita in the long run.

The short run estimation results reveal that electric power consumption has a positive and significant impact on GDP per capita in the short run implying that electricity is important for Botswana's economic growth. However, education infrastructure was found to have a negative and significant impact on economic growth in the short run. The study establishes that this may be due to the longevity of interaction between education infrastructure and economic growth. Healthcare infrastructure and the total length of roads maintained by central government were found to have no significant impact on economic growth in the short run.

A couple of control variables were included in the analysis and these included trade openness and the lending real interest rate. Consistent with economic theory, trade openness was found to significantly and positively contribute to economic growth in the short run and in the long run. However, the lending real interest rate was found have no significant effect in influencing economic growth in Botswana in both the short run and the long run.

In conclusion, the results reveal that healthcare infrastructure is important for the long-term economic growth in Botswana. It is widely accepted that health is an important element of human capital formation, and that the improvement of health produces a positive effect on the generation of economic growth and productivity. Therefore, it should be in the interest of policymakers to prioritise improvement of healthcare infrastructure in order to spur economic growth of the country.

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# APPENDICES

## Table 1A: ADF Unit Root Test

| Variable | Level | | | | First Difference | | | |
|---|---|---|---|---|---|---|---|---|
| | Intercept | Trend & Intercept | None | Order | Intercept | Trend & Intercept | None | Order |
| lnGDPPC | -4.492 | -5.030 | -3.117 | I(0) | | | | |
| lnHEF | -5.323* | -3.223 | 5.122 | I(0) | | | | |
| lnSCE | -1.651 | -3.314 | 4.898* | I(0) | | | | |
| lnEPC | -0.481 | -4.946* | 4.344 | I(0) | | | | |
| lnTAR | -4.417* | -0.967 | 1.046 | I(0) | | | | |
| lnTO | -1.859 | -1.612 | -0.350 | | -5.784 | -5.869 | | I(1) |
| RIR | -3.727 | -3.796* | -3.049 | I(0) | | | | |
| 5% critical value | -2.948 | -3.544 | -1.950 | | - 2.951 | -3.548 | | |

## Table 2A: PP Unit Root Test

| Variable | Level | | | | First Difference | | | |
|---|---|---|---|---|---|---|---|---|
| | Intercept | Trend & Intercept | None | Order | Intercept | Trend & Intercept | None | Order |
| lnGDPPC | -4.492 | -4.973 | -2.982 | I(0) | | | | |
| lnHEF | -6.993 | -5.178 | 4.586 | I(0) | | | | |
| lnSCE | -1.585 | -2.538 | 4.166 | I(0) | | | | |
| lnEPC | -0.968 | -3.652 | 6.056 | I(0) | | | | |
| lnTAR | -4.417 | -0.977 | 1.547 | I(0) | | | | |
| lnTO | -1.871 | -1.634 | -0.350 | | -5.784 | -5.879 | | I(1) |
| RIR | -3.682 | -3.631 | -2.995 | I(0) | | | | |
| 5% critical value | -2.948 | -3.544 | -1.950 | | - 2.951 | -3.548 | | |

## Table 3A: Lag Length Selection

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | -88.125 | NA | 22.525 | 5.945 | 6.265 | 6.051 |
| 1 | -84.896 | 4.843* | 19.667* | 5.806* | 6.172* | 5.927* |
| 2 | -84.124 | 1.110 | 20.044 | 5.820 | 6.232 | 5.956 |
| 3 | -84.124 | 7.720 | 21.467 | 5.882 | 6.340 | 6.034 |

*indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

### Table 4A: Diagnostics Tests for the short run Model

| Diagnostic Test | P Value | Significance | Decision Rule |
|---|---|---|---|
| LM Serial Correlation | 0.149 | 5% = 0.05 | Reject H0 if P > S |
| H0: No Serial Correlation | | | |
| Ramsey Reset Test | 0.092 | 5% = 0.05 | Reject H0 if P > S |
| H0: Model correctly specified | | | |
| ARCH Heteroskedasticity | 0.379 | 5% = 0.05 | Reject H0 if P > S |
| H0:Homoskedasticity | | | |
| White Heteroskedasticity | 0.387 | 5% = 0.05 | Reject H0 if P > S |
| H0: Homoskedasticity | | | |
| Normal Distribution | 0.926 | 5% = 0.05 | Reject H0 if P > S |
| H0:Residuals normally distributed | | | |

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