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*Research Article*

# AUTOMATED DETECTION OF STRUCTURAL CHANGE IN BOTSWANA GROSS DOMESTIC PRODUCT (GDP) USING NOVEL ALGORITHM

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**ABSTRACT:** The main objective of this study is to examine the phenomenon, Structural change in the gross domestic product of Botswana and possible forecast and recommend for future adjustment. Gross fixed capital formation (% of GDP). Botswana Gross Domestic Product (GDP) data and some resource materials were obtained from the data stream of Universiti Utara Malaysia and National University Singapore library. In the methodology, BFAST (Break for additive, Season and trend) was used to examine the structural change, time series components present in the data (Botswana GDP) using R and Python software. BFTSC was created to capture the trend, seasonal, cyclical and irregular components as automated combined image and to present them in a single plot. The result obtained, model acquired from the components (pattern) extracted using BFTSC was subsequently processed for forecasting purposes and recommendation follows. The real data findings suggested that BFTSC can provide a better time series components identification better than manual process and hence should be taken seriously. Botswana GDP is gradually declining; caution should be taken to improve the GDP such that Botswana can have bounty reserve and can also loan poor and financial weak countries. Improvement Botswana GDP is recommended.

**KEYWORDS**: Botswana, Gross Domestic Product, Break for Time Series Components, Forecast, Control, Trend Change.

## 1. INTRODUCTION

This study uses BFTSC (Break for time series components) to identify the components of time series present in the empirical data which is the GDP yearly data of Botswana GDP gross domestic product. BFTSC is considered to be more efficient in identifying all the components of time series statistics better than manual approach and BFAST. (29) Recommended an approach of basic swing identification to spot time series component. This approach was also used by (23) as the latest time series component recognition approach which is a technique that was first described and utilized by (33).

The technique BFAST was for recognizing breaking points with the help of seasonal and trend decomposition using loess (STL), it facilitates the detection of trend change in a given information. The elementary standard of BFAST technique is the splitting of time series into seasonal, trend and also remnants element by the approach for breaks detecting software in R studio core 2012 **(**10).

The economy of Botswana was one of the world's fastest growing economies before Covid 19, averaging about 5% per annum over the past decade. Growth in private sector employment averaged about 10% per annum during the first 30 years of the country's independence. After a period of stagnation at the turn of the 21st century, Botswana's economy registered strong levels of growth, with GDP growth exceeding 6–7% targets. Botswana has been praised by the African Development Bank for sustaining one of the world's longest economic booms. Economic growth since the late 1960s has been on par with some of Asia's largest economies. The government has consistently maintained budget surpluses in the past and has extensive foreign-exchange reserves. Botswana's impressive economic record compared to some of its neighbors has been built on a foundation of diamond mining, prudent fiscal policies, and a cautious foreign policy. Botswana's economy is mostly dependent on diamond mining. Diamond mining contributes to 50% of the government revenue mainly through its 50:50 joint venture with De Beers in the Debswana Diamond Company. It is rated as the least corrupt country in Africa in the Corruption Perceptions Index by international corruption watchdog Transparency

International. It has the fourth highest gross national income per capital in purchasing power in Africa and above the world average (39).
Trade unions represent a minority of workers in the Botswana economy. In general they are loosely organized "in-house" unions, although the Botswana Federation of Trade Unions (BFTU) is consolidating its role as the sole national trade union center in the country. Although Botswana's economy is considered a model for countries in the region, its overreliance on mining and its high rate of HIV/AIDS infection (one in every three adults is seropositive) and unemployment may threaten its future success. Man on donkey herding goats in a dry river bed GDP per capita (current), compared to neighboring countries (world average = 100) Agriculture still provides a livelihood for 70% of the rural population but supplies only about 50% of food needs and accounted for only 1.8% of GDP as of 2016. Subsistence farming and cattle raising predominate. The sector is plagued by erratic rainfall and poor soils. Diamond mining and tourism are also important to the economy. Substantial mineral deposits were found in the 1970s and the mining sector grew from 25% of GDP in 1980 to 38% in 1998. Unemployment officially stood at 21% as of 2000 but unofficial estimates placed it closer to 40%. Economic growth slowed in 2005–2008 and turned negative in 2009 as a result of the Great Recession, contracting by 5.2%. This was exacerbated by a major global downturn in the industrial sector, which shrank by 30%, Botswana's steep economic downturn contrasted with most other African nations which experienced continued growth through this period (39).

Botswana's budget deficits can be traced to relatively high military expenditures (about 4% of GDP in 2004, according to the CIA World Fact book). Some critics have criticized this level of military spending, given the low likelihood of international conflict, though these troops are also used for multilateral operations and assistance efforts. Botswana is crossed by the trans-African automobile route - the Cairo-Cape Town Highway and the Trans-Kalahari Corridor. Botswana is part of the Southern African Customs Union (SACU) with South Africa, Lesotho, Eswatini, and Namibia. The World Bank reports that in 2001 (the most recent year for which World Bank data is available), the SACU had a weighted average common external tariff rate of 3.6%. According to the U.S. Department of Commerce, "there are very few tariff or non-tariff barriers to trade with Botswana, apart from restrictions on licensing for some business operations, which are reserved for [Botswana] companies." Based on the revised trade factor methodology, Botswana's trade policy score is unchanged (39).

The main export of Botswana is diamonds. As of 2017 it is the world's second largest producer of diamonds after Russia. Due to Botswana's heavy reliance on diamonds, strong global demand is vital to the health of the economy. Diamond exports provide Botswana's economy with strong supplies of foreign exchange and have offered a basis for industrial development and stimulated improvements in Botswana's infrastructure. However, despite their preeminent role in Botswana's economy, there are concerns that diamond mines are not labour-intensive enough to provide sufficient employment for Botswana's workforce, and this mismatch has been cited as a factor in the country's structurally high unemployment rate. Two large mining companies, Debswana (formed by the government and South Africa's De Beers in equal partnership) and Bamangwato Concessions, Ltd. (BCL, also with substantial government equity participation) operate in the country. BCL was placed in provisional liquidation in late 2016, following years of loss-making operations, and was placed into final liquidation by the High Court in June 2017. The Jwaneng diamond mine is the richest in the world today (39).

Since early 1980s, the country has been one of the world's largest producers of gem diamonds. Four large diamond mines have opened since independence. De Beers prospectors discovered diamonds in northern Botswana in the early 1970s. The first mine began production at Orapa in 1972, followed by a smaller mine at Letlhakane. What has become the single richest diamond mine in the world opened in Jwaneng in 1982. The mine was discovered when termites looking for water brought grains of diamond to the surface. Botswana produced a total of 21.3 million carats of diamonds from the three Debswana mines in 1999, and is the highest producer of diamonds by value in the world. The Orapa 2000 Expansion of the existing Orapa mine was opened in 2000. According to Debswana, the Orapa 2000 Expansion project increase the Orapa's mine annual output from 6 million carats to 12 million carats and raised total production to 26 million carats. In 2003, Debswana opened the Damtshaa diamond mine about 220 kilometers (140 mi) west of the city of Francistown. The mine was placed into care and maintenance in December 2015 due to weak global demand but was scheduled to reopen in January 2018. In 2008, Australia's Kimberley Diamond Company opened a mine in Lerala, Botswana's fifth mine and the first not operated by Debswana. However, Kimberley shut down the mine in May 2017, citing weak market conditions (39).

Most (70%) of Botswana's electricity is imported from South Africa's Eskom. 80% of domestic production is concentrated in one plant, Morupule Power Station near Palapye, operated by the Botswana Power Corporation. Debswana operates the nearby Morupule Colliery to supply coal to it. The Morupule mine exports coal to Zimbabwe, Zambia and the Democratic Republic of the Congo. In early 2008, the entire southern African region was hit hard by massive shortages of power, since the region works to share its power resources through the Southern African Power Pool, with most of its capacity coming from South Africa. Botswana has in turn put in place plans to become a net exporter of power to the regional pool, through governmental expansion of the Morupule power station, as well as encouraging private investment in the form of a 4 gigawatt power station by the Canadian greenfield company CIC Energy. In 2012, CIC Energy was acquired by India's Jindal Steel and Power. Jindal Africa currently aims to operate three surface mines in the coalfields of Mmamabula, as well as a power plant. According to the company, "the mine's development will meet the demands of 600MW power stations and export region coal markets, with the potential to employ more than 2,000 people (39).

Botswana also produces soda ash through Botash, a joint venture between the government and South Africa's Chlor-Alkali Holdings (CAH) Group. Botash has been operating in the Sua Pan in northeastern Botswana since April 1991. Production of soda ash is estimated at around 300,000 tonnes per annum and is exported to South Africa, Zambia, Zimbabwe, Malawi and the Democratic Republic of the Congo. The technique BFAST was for recognizing breaking points with the help of seasonal and trend decomposition using loess (STL), it facilitates the detection of trend change in a given information. The elementary standard of the BFAST technique is the splitting of time series into seasonal, trend and also remnants element by the approach for breaks detecting software in R studio core 2012 (10).

**MATERIAL AND METHODS**

BFAST is the technique used in analyzing the generality of time series data by extracting the trend and seasonal pattern during time series decomposition. Given the general time series additive model of the form of equation 1.1 (27, 28 and 36).

From equation (1.2) BFAST takes all other components relatively trend and seasonal component to be randomized ($R_p$) and the equation was expressed as

$$Y_P = T_p + S_p + R_p \quad (1.2)$$

The residual random consist of cyclical and irregular component (17, 18, 19, 20, and 22).

To generate trend components using BFAST, we need a piecewise linear model approach. Suppose $T_p$ is a piecewise linear model with an actual slope and intercept on q+1 segments broken with q breakpoints and P period; $p^{\neq}_1,\ldots\ldots\ldots, p^{\neq}_q$ then $T_p$ can takes the form as follows

$$T_p = \alpha_k + \beta_k P$$

Where $p^{\neq}_{k-1} < p \leq p^{\neq}_k$

And If $k = 1,\ldots..,q$ then $p^{\neq}_0 = 0$ and $p^{\neq}_{q+1} = n$.

The slope of the change before the breakpoints while $\beta_{k-1}$ and the slope of the breaks after the change breakpoints are $\beta_k$. The intercept and the slop of the linear model $\alpha_k$ and $\beta_k$ with time period p and it will be used to derive the magnitude and direction of change (1, 2, 3, 4, and 5).

To generate seasonal components using BFAST, we need a simple harmonic model.

Thus, $S_p$ can be represented by a simple harmonic model with j terms; j = 12….J and time t.

$$S_p = \sum_{j=1}^{J} \omega_{k,j} \ \mathrm{Sin}\left(\frac{2\pi jt}{F} + \sigma_{K,j}\right) \quad (1.3)$$

Where k = 1… q, $p^{\neq}_{k-1} < p \leq p^{\neq}_k$ and also $\omega_{k,j}$, $\sigma_{K,j}$ are the segment amplitude and F is the frequency (1, 2, 3).

To generate random components, any data that does not belong to trend nor seasonal is classified random$R_p$.

$$\dot{Y}_P = \underbrace{\{\alpha_k + \beta_k P\}}_{T_p} + \underbrace{\{\sum^{J}_{j=1} \omega_{k,j} \ \mathrm{Sin}\left(\frac{2\pi jt}{F} + \sigma_{K,j}\right)\}}_{S_p} + \underbrace{R_p}_{R_p} \quad (1.4)$$

$$Y_P = T_p + S_p + R_p$$

The new technique called BFTSC considered splitting the random into cyclical components and irregular components which is an extension of BFAST. This was done through the inclusion of two new components.

To calculate cyclical components, center moving average is involved (14, 15, and 16).

Derivation of cyclical code, let CMA be the center moving average of t objects, then CMA can be computed as follow

$$CMA = \sum_t^n \frac{Y_t}{nt} \quad (1.5)$$

$$C_p = \frac{CMA}{\frac{A}{CMA}} \qquad (1.7)$$

After extracting the trend, seasonal and cyclical components, the left out components is called irregular components, the new equation becomes

$$Y_P = \underbrace{\{\alpha_k + \beta_k P\}}_{T_p} + \underbrace{\{\sum_{j=1}^{J} \omega_{k,j} \sin\left(\frac{2\pi jt}{F} + \sigma_{K,j}\right)\}}_{S_p} + \underbrace{\{\frac{CMA}{\frac{A}{CMA}}\}}_{C_p} + \underbrace{\{I\}}_{I_p} \qquad (1.8)$$

$$Y_P = T_p + S_p + C_p + I_p$$

For identification of $Y_P$ , $S_p$ , $C_p$ , and $I_p$ ( See the paper: 5,6, 33).

The first stage in forecasting is to view the data and to examine all the components of time series present in that data in order to select the most appropriate forecasting technique (See figure 1). The Botswana yearly GDP data components identification was carried out with the help of the new technique called BFTSC. This new technique helps to have a clear image of the entire variations presents in the time series data (1, 2, 3 and 4).

2.

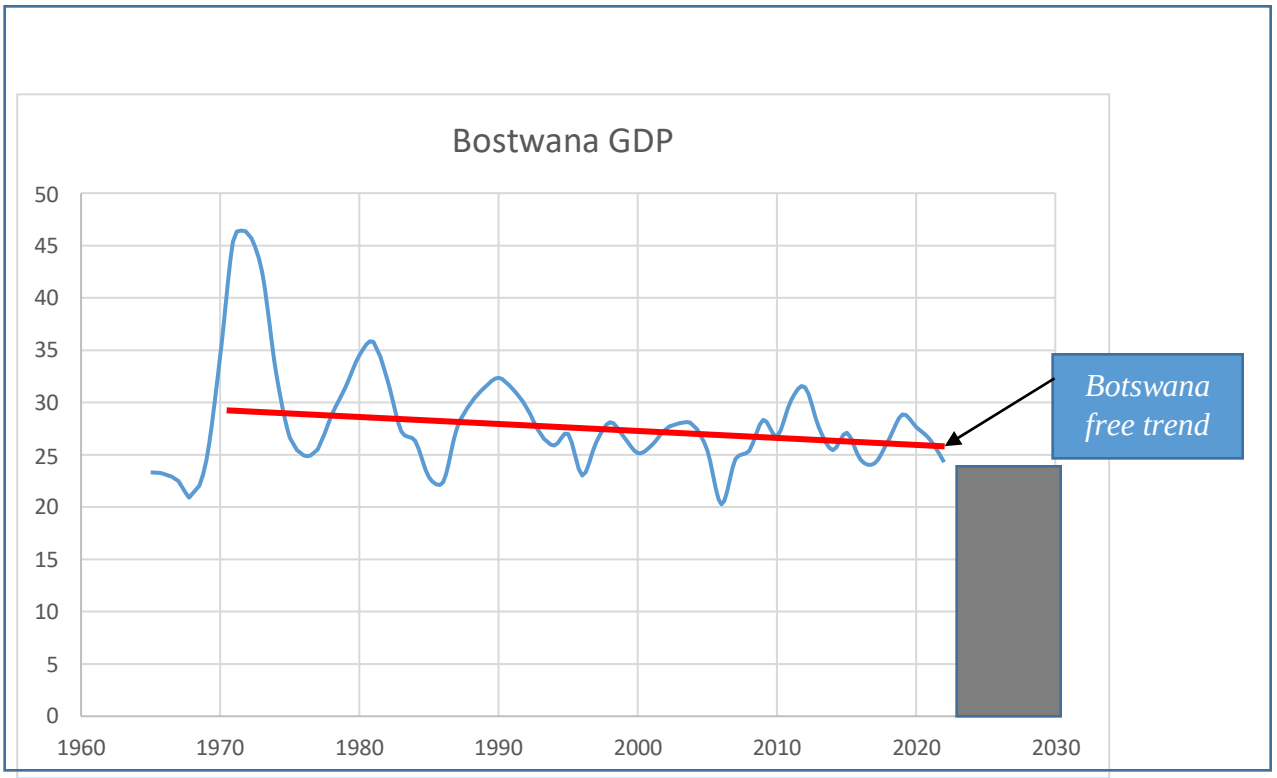


**Figure 1. Original Manual Botswana Gross Domestic Product (GDP) plot**.

The free fitted value and the real data of the Botswana Gross Domestic Product (GDP) (figure ). This reveal that for the next ten years period9from 2020), the Botswana Gross Domestic Product (GDP show evidence of decline and the fitted value did not fit well and match intact to the original Botswana Gross Domestic Product (GDP) data so the model can be applied for prediction of more years GDP of Botswana.

Figure 2 reveals all the time series components hidden in the Botswana Gross Domestic Product (GDP) data for some selected years, the image in the figure above indicates the presence of trend, seasonal, cyclical and irregular components, Hence the most appropriate technique for analyzing such data is ARIMA.
Automated ARIMA models were fitted, and the best model was selected based on the ARIMA with the smallest AIC (Akaike's Information Criterion). Based on the AIC models, the ARIMA (1, 2, 3) is the best model to be used in fitting the UK quarterly GDP. ARIMA (1,2,3) is selected and used for fitting the model.

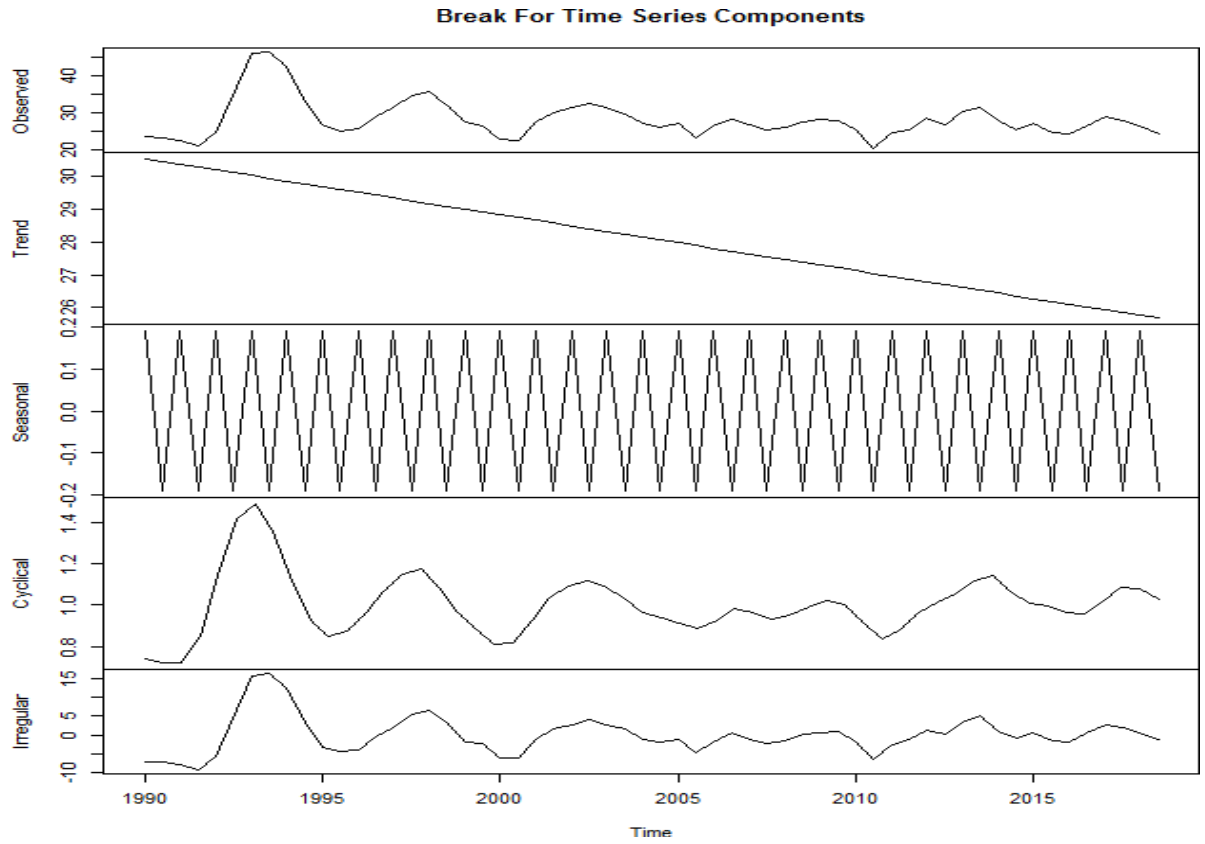


**Figure 2.** BFTSC for Botswana Gross Domestic Product (GDP)

**RESULTS**

Based on figure 1 and figure 2, the Botswana GDP is sliding into bankrupt, and based on the forecast value, the GDP of Botswana show some scientific evidence of dropping in the next five years. This reveal that for the next five years period, the Botswana Gross Domestic Product (GDP) show evidence of decline and the fitted value did not fit well and not match intact to the original Botswana Gross Domestic Product (GDP) data so the model can be applied for more prediction of more years GDP of Botswana. If Botswana government did not take action quickly? By end of 2020, 2021, 2022 the economy will have serious financial instability and drawback problems.

This should not be taken for levity but with all seriousness to make the Botswana GDP grow beyond prediction and beyond expectation. The forecast should not stop the country from improving and investing in the country GDP so as to have blossom reserve. Botswana should employ all other possible means of generating revenue (both internally and externally) for the country utilization.

BFTSC is the most appropriate for time series components identification. BFTSC is recommended as a good alternative to BFAST. This is because BFTSC identifies the four components of time series statistics which is one of the basic limitations of BFAST, BFTSC. Based on the forecast value for five years, it reveals some scientific evidence of drop and crash in Botswana GDP so improvement can be establish to improve on the yearly Botswana GDP. The contribution of this study to the scientific community is that the BFTSC gives good results that improve the weaknesses of the existing BFAST. BFTSC forecast output is more reasonable for effective policy making.

Note: The data, BFTSC and GFTSC can be made available based on request from the authors author of this paper Dr. Ajare Emmanuel. The data utilized in this study is available freely if the author is contacted. The BFTSC or GFTSC can

be acquired with $10,000 from Dr Ajare Emmanuel. The forecast in this Botswana GDP can likewise be acquired with $1000 per year per forecast. This forecast is very good for policy making and economic development. (ajareoloruntoba@gmail.com and **ajare_emmanuel@ahsgs.uum.edu.my**).

**Discussion/Conclusion**

The technique BFAST was for recognizing Breaks for Additive Seasonal and Trend (BFAST). This technique helps to recognize trend breaks enclosed by the series. The essential guide of the BFAST technique is the decomposition of time series components into seasonal, trends and miscellany elements with the technique for recognizing structural similarity and difference. Verbesselt et al. (2010) recommended that the technique of BFAST is for identifying topographical patterns and also for improvement to be applied in other related disciplines (33).

Jamali, Jönsson, Eklundh, Ardö, and Seaquist (2015) describe BFAST as not being capable of identifying topographical vegetation basic component perfectly, though satellite sensor image has made topographical vegetation data available for so many years but yet the detection of topographic trend and variation is not yet clearly defined. Chen (2006) suggested that this may be due to the limited number of available trend and change detection techniques accessible, algorithm suitable in identifying and characterizing abrupt changes without sacrificing accuracy and efficiency.

Based on previous studies, BFAST is used for topographical green forest picture data at certain specific time. Introducing BFAST to time series data and how to implement BFAST on time series data which contain only one variable for each time is another form of challenge. BFAST is a technique that takes in data and processed to extract each component point of the data, it would be reasonable to use BFAST for time series components identifications (32,33,34).

BFAST approach give a very considerable outcome and was recommend as a modern instrument for statistics information decomposition and detections but could not separate random noise and is a customized additive decomposition method, from all indication observed so far, it reveals that BFAST need to be extended for the purpose of coping with other varieties of uses (27,28,29).

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**(ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

**Authors Contributions**

Ajare Emmanuel Oloruntoba, Analyzing and writing the paper. Shobanke Dolapo Abidemi and Adeyemo Abiodun both contributed in the technical writing and development of this paper, Adefabi Adekunle facilitated the development of the technique utilized to producing the results.

**Ethics**

This is the original manuscript by the authors, technique is uniquely created and applied; there will be no expectation of any ethical problems.

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