Revisiting Wagner's Law: An econometric analysis for South Africa (1960-2024)[1]

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Abstract

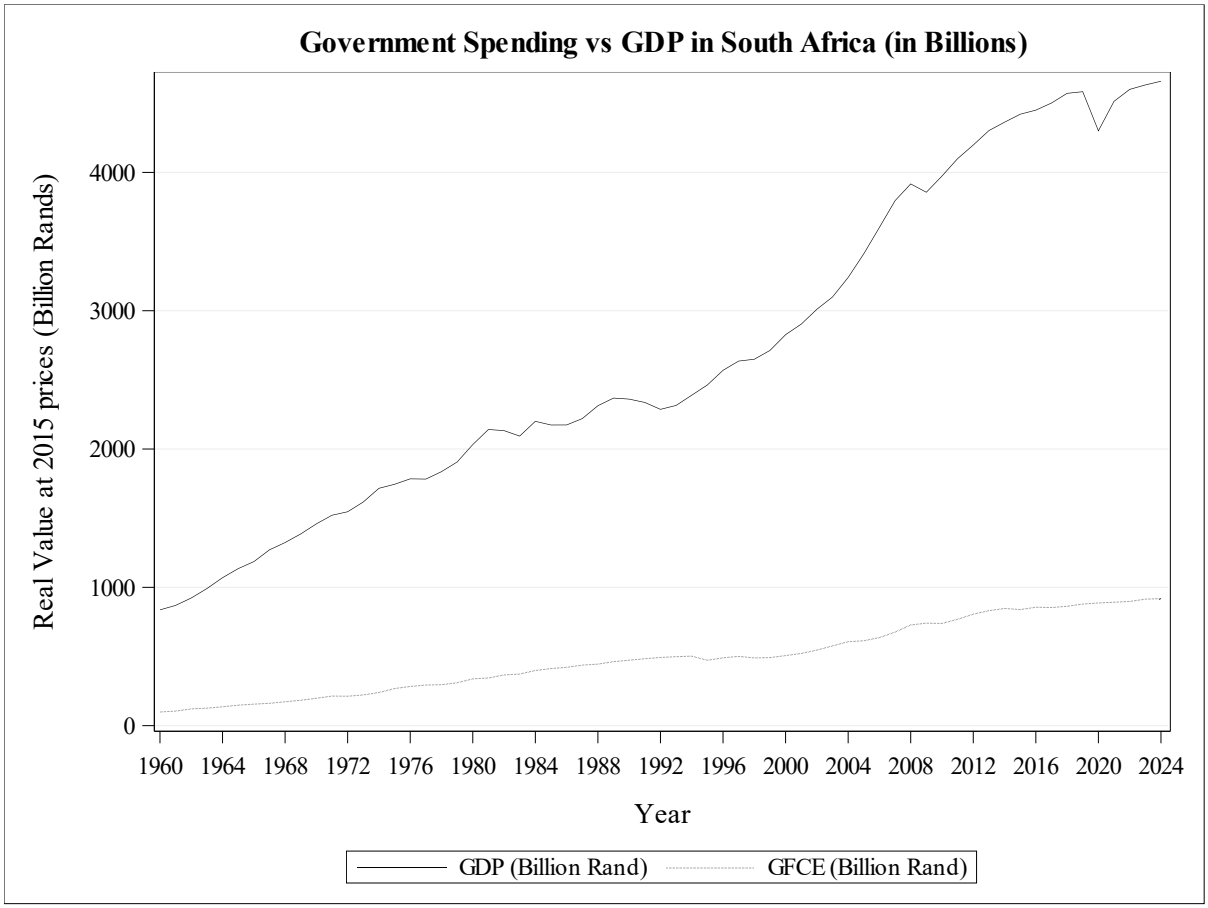
This paper re-examines Wagner's Law in a South African context over the period 1960-2024. Wagner's Law suggests that for an increase in real national income, the government final expenditure gradually expands more proportionally than GDP, due to a higher income elasticity of demand for collective goods. While the contras to Wagner's assumption is fiscal spending acts as a driver of economic activity (i.e. Keynesian theory). By using annual data on real gross domestic product (GDP) and general government final consumption expenditure (GFCE) at constant 2015 prices, valued at local currency, we will first test for stationarity. Further we will estimate the elasticity coefficient through autoregressive models and assess causality by vector autoregression. Considering both long run proportionality and short run dynamics, this study contributes to the fiscal to growth nexus in developing economies. It such that follows that policy implications are discussed in terms of South Africa's fiscal challenges.

1. Introduction

The role of the government, in modern economies is extensive and multifaceted, and remains a subject of ongoing debate. There are two prominent theoretical frameworks that shape our understanding of the relationship between government expenditure and GDP. Wagner's Law, postulates that as a country's real income increases, the public spending rises disproportionately due to the drive of the demand on public services and goods such as infrastructure, legal administration and social welfare. In contrast by asserting Keynesian theory, the exogenous role of substantial public spending stimulates aggregate demand and thereby induce economic growth.

Throughout 1960-2024, South Africa's government final consumption expenditure proportion rose from 11.8% of GDP in 1960, to approximately 20% by 2024, whilst real GDP per capita more than doubled (*Figure 1*). These trends thereby prompt a central question: Does economic growth naturally lead to higher government spending, or does government spending fuel economic growth? By resolving the question, a robust econometric analysis is required, since fiscal implication surrounding the theories differ significantly. If Wagner's Law holds within South Africa, then budgeting frameworks may shift towards a disproportional rise in public spending. However if the Keynesian dynamics dominate, then accurate fiscal interventions can stabilize economic growth.

Figure 1:GDP and Government expenditure in South Africa (1960-2024)



Source 1: Author's computation

This study applies contemporary time-series techniques to test Wagner's Law in South Africa by using log-log modelling, AR (1) corrected estimation, and the VAR – Granger – causality test.

2. Literature Review

Wagner's law is based on three foundational assumptions. Firstly, with economic growth there is an increasing and continuous implementation of regulation and laws to satisfy legal and administrative functions. Secondly, there is a need for government intervention due to the subsequent growth in negative externalities caused by urbanization and industrialization. Lastly, any public good (education, health, and infrastructure) has a relatively higher income elasticity of demand, implying that these goods are consumed disproportionately as income rises.

Essentially Wagner's Law defines the stages of development within an economy. In initial development there is a need for government to create and uphold regulations, this must however be followed with effective legal and administrative institutions[1]. It follows that in the pre – industrial stages, government spending is at an all time high, however this brings in the implication of capital accruement and budget deficits. Proceeding the initial phase, the

[1] In early stages of development, a higher government intervention is needed within the economy, meaning there is a need to provide basic infrastructure and an environment that will promote economic growth.

government will continue to provide investments goods and services, which will seemingly attract private investment[2]. By a higher influx of investment expenditure, GDP will rise. In the final stages of development government expenditure decreases since infrastructure necessities have declined, however expenditure on social goods (education, healthcare, social/welfare programs) generally increase. With a higher expenditure on social goods, the income elasticity of demand increases relative to the expenditure, thereby there is a continuous increase in the share of the government within an economy (Siebrits, 2023).

Econometrically, the mathematical expression for Wagner's Law is represented by the equation:

Equation 1: Wagner's Law expression

$$\log(\mathrm{GFCE_t}) = \beta_0 + \beta_1 \log(\mathrm{GDP_t}) + \varepsilon_t$$

where $GFCE_t$ defines government final consumption expenditure, GDP_t represents the output/economic activity, ε_t the error term, and t being a time point. For the existing expression, Wagner's hypothesis holds if $\beta_1 > 1$. Additionally Wagner's assumptions holds if the following assumptions are met: there must be a rising per capita income, and/or rising real GDP; innovation must take place in the form of technological and institutional changes; there must be an assumption of democratization (Siebrits, 2023).

Conversely, the Keynesian theory emphasises that an exogenous increase in government spending can stimulate GDP since the fiscal interventions are mechanisms to counteract economic downturns and boost aggregate demand, due to the fiscal multiplier effect. This is subsequent to the normality assumption of the trade, public, private and household sectors such that the following remains true:

Equation 2: Keynesian expression

$$\log(GDP_t) = \frac{\gamma_1}{\eta_1}\log(CFE_t) + \gamma_2 \log(GFCE_t) + \gamma_3 \log(PVCI_t) + \eta_2 \log(IT_t) + \varepsilon_t$$

For γ_i be income indicators and η_i be the production good.

'Wagner's Law is underpinned by three assumptions: (1) economic growth requires expanding legal and administrative functions; (2) industrialization and urbanization generate externalities requiring government intervention; and (3) social and infrastructural goods exhibit high income elasticities of demand. Collectively, these imply a rising share of government expenditure as economies develop (Siebrits, 2023).

Empirical evidence is mixed. In advanced economies, elasticity coefficients often exceed one, supporting Wagner's Law. In developing economies, results vary due to institutional constraints, data quality, and methodological differences. For South Africa, Phiri (2016) found nonlinear support for Wagner's Law, while Smith and Khumalo (2019) reported elasticity above unity but ambiguous causality. Mehta (2024), in a BRICS study, confirmed Wagnerian dynamics across emerging economies.

Critics argue that Wagner's framework overlooks efficiency and governance issues, particularly in contexts where rising public spending may not translate into welfare-enhancing outcomes. This motivates a dual perspective: testing Wagnerian elasticity

[2] The inflow of investments are a result of a positive pecuniary externality by the public sector investments in the initial phases of development.

alongside Keynesian causality provides a more comprehensive understanding of the fiscal-growth nexus.'

3. Empirical Evidence

Numerous endeavors were completed to successfully show the validity of Wagner's Law; however, the evidence is rather counterproductive. The mixed outcomes on Wagner's Law often depend on the data quality, econometric techniques and specific intended hypothesis.

In advanced economies the elasticity coefficient (β_1) often exceeds one, suggesting that government spending rises more than proportionally with income. *For instance, studies on Western Europe and North America report strong Wagnerian support, often linked to higher demand for welfare services, infrastructure, and regulatory frameworks in mature economies (Henrekson, 1993; Lamartina & Zaghini, 2011).*

Whereas in developing economies the analysis has often produced mixed results, due to institutional differences, data limitations and methodical inconsistencies. With Wagner's law economist have assumed there is no allowance made for the efficiency implications of a rise in the share of the government or in the public choice. Another critique is that Wagner's Law reflects a rather organic view of an economy, in composite with the mechanistic view of a government (Siebrits, 2023).

Wagner's hypothesis demonstrates mixed and complex support within South Africa. In 2016 a paper produced a significant positive long run coefficients in a range of 0.04-4.458 for nonlinearities in Wagner's law (Phiri, 2016).Other South African studies estimated a significant elasticity coefficient. in varying subperiods but did not all fully correct for serial correlation nor examine causality. A recent working paper by Smith and Khumalo (2019) revisited South Africa with cointegration and VECM methods and found an elasticity estimate above unity $\beta \approx 1.05$ but founded ambiguous causality[3]. A more recently a study on BRICS countries (to which includes South Africa) confirmed Wagner's Law, such that the study showed a positive relationship between national income and government size, even though the Keynesian assumptions was generally relevant (Mehta, 2024)

In conjunction with both of the empirical evidence (supporting Wagner or the Keynesian theory) there is an underlying suggestion that Wagner's Law is not a universal law but a conditional relationship. Wagner's validity is somewhat sensitive to the following cases: (I) the income measurement, (II) the econometric determination and (III) the historical component of structural change in economies.

In a South African perspective, Wagner's Law is a relative challenging concept, since there is a potential of non – linearities, structural breaks[4] and causality dynamics.

Building on these papers, we employ an AR (1) -corrected GLS model for robust elasticity inference and VAR Granger-tests for directional dynamics.

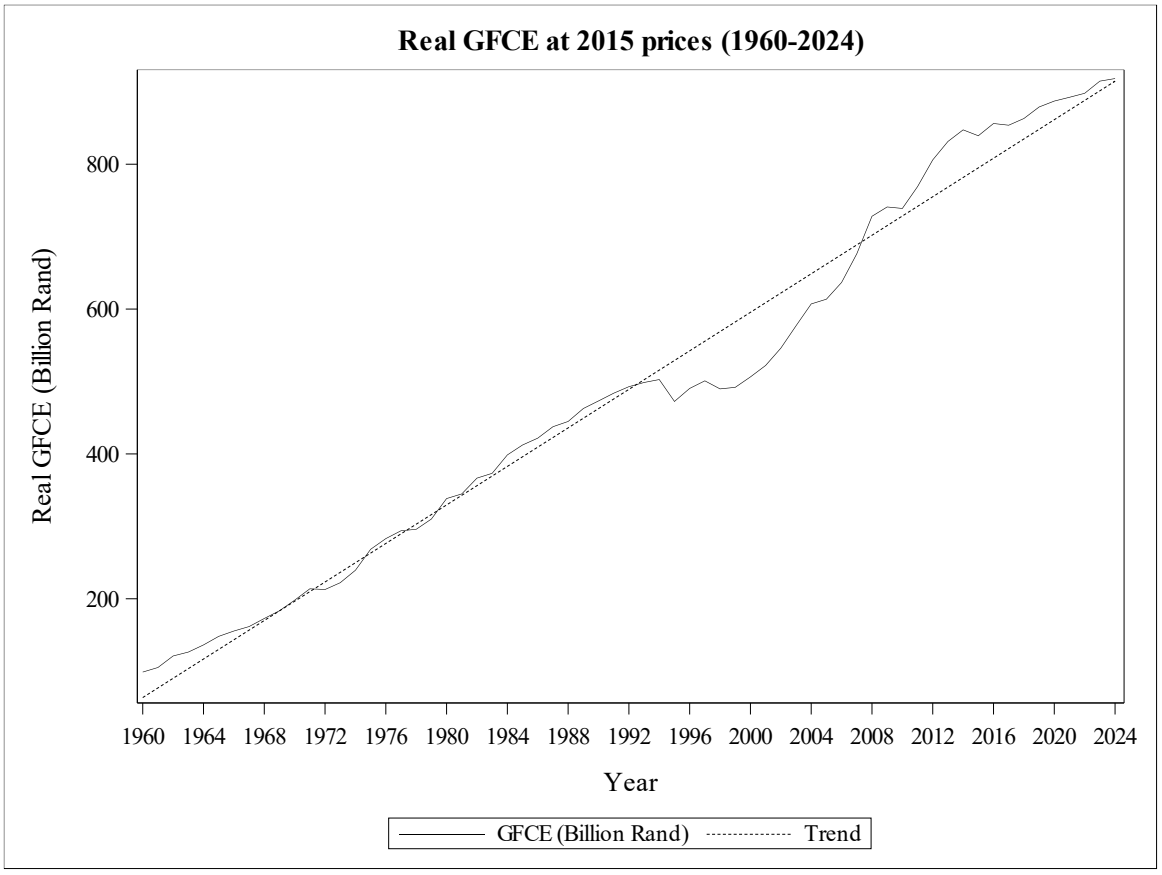
[3] With the ambiguous causality the bidirectional relationship between real GDP growth and real government consumption expenditure was only weakly supported.
[4] Structural break defines for if South Africa was in an apartheid era or in a post – apartheid era

4. Public expenditure and economic growth

After apartheid ended in 1994, South Africa's budgetary objectives changed to include healthcare, education, and societal welfare, whereas the pro-apartheid government prioritised military and admirative spending. Government spending increased from R98.78 billion in 1960 to approximately R918 billion in 2024, all prices adjusted for 2015.

It is important to note that from 1993 (the prenuptial year before the end of apartheid, but nevertheless during) real government spending growth fell by 0.693%. This resulted in a stagnant growth between 1994-20007. In conjunction, per the budgetary objectives, the decline was not due to government inefficiencies, rather due to the rigorous fiscal policy consolidations. The decline was ultimately to contradict the unsustainable spending and economic uncertainty by decreasing spending to sectors as defence and the general administration (Hortin, 2006). Further on government expenditure growth above the trend line form 2007 and onwards from notable economic shocks such as the Global Financial crisis in 2008 and the COVID-19 pandemic in 2019. Even though the real GDP fell in 2008 and 2019-2020, government expenditure rose due to a fiscal stimulus package and public expenditure on societal and health goods. The fiscal stimulus package was deployed to prevent a further economic contraction and ultimately counteract the sharp fall in consumer demand. Similarly public spending grew in 2019 in response to counteract the depletion of healthcare goods, healthcare services and to ensure economic relief for business and households.

Figure 2: Total Government Final Consumption expenditure in South Africa (1960-2024)



Source 2: Author's computation

During the same time span, real GDP grew from approximately R837 billion to R4 trillion. However, the long-term economic output however deviates significantly from the trend. Prominently the stagnation in real GDP at constant prices, during 1960-1994, was due to the country's discriminatory regime (Arora, 2006). The apartheid era resulted in disinvestment and international sanctions. Under the apartheid government, foreign countries imposed trade sanctions with South Africa, similarly the global economy retracted an influx of investment capital towards South Africa (South African Reserve Bank, 2020). The state of South Africa's economy ultimately deterred economic progress, which led to a decline in modernisation, innovation and a stable economic growth rate.

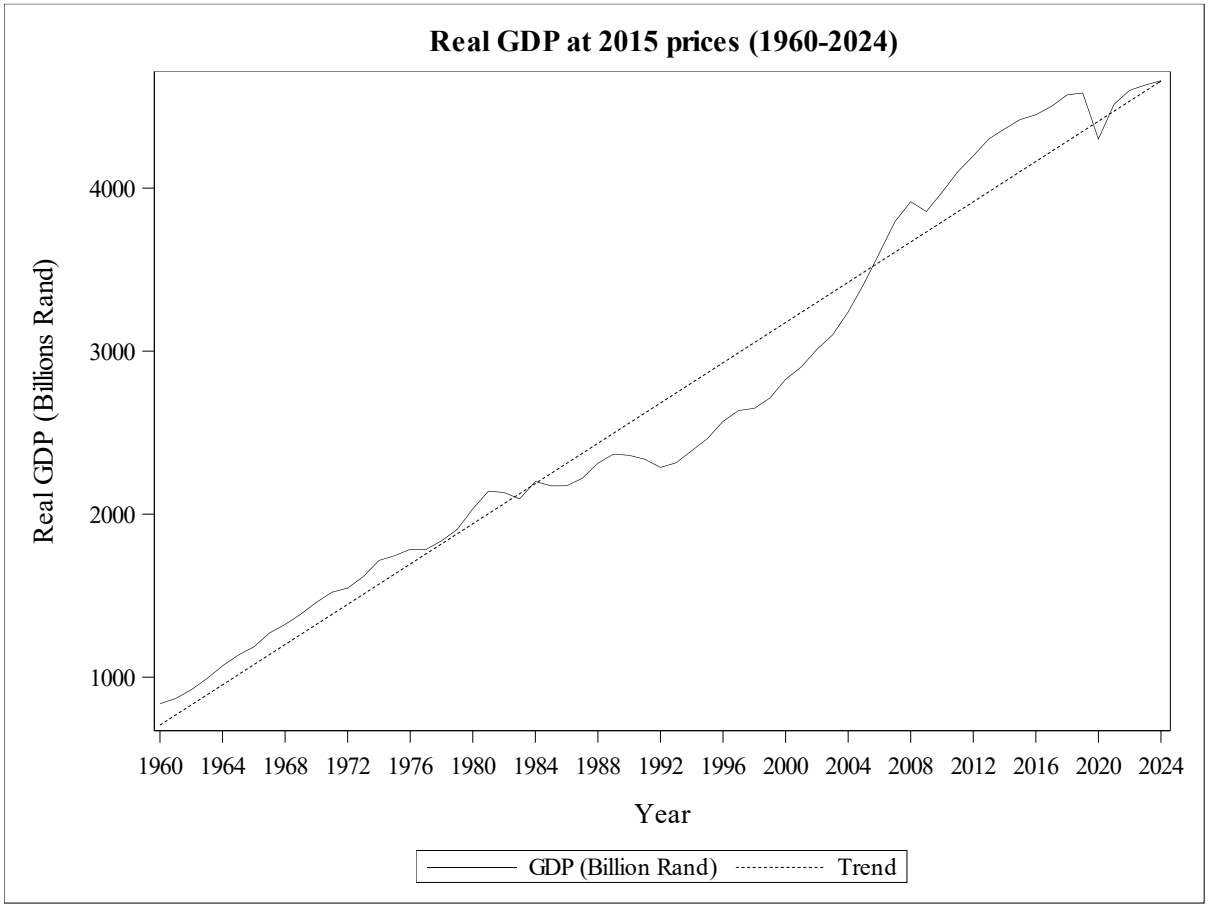
In subsequent years (1994-2005), the real GDP grew by 2.08%. The disintegration of economic sanctions allowed for an increase in foreign investment and trade, resulting in a higher influx of global capital gains, production and innovation. As per the government consumption, the fiscal consolidations towards the previous regimes spending, restored investor confidence and interest rates. From 2006 onwards the economy produced a higher output than potential output.

Relatively real GDP per capita declined[5] during 1980-1994, which suggest that there was a decline in economic prosperity of the average person. Again, due to the apartheid regime, structural inefficiencies deterred skilled labour and a higher consumer demand from the country[6]. Even though South Africa faced structural, cultural and economic deficiencies, the country progressed to promote higher societal gain was reached and in turn economic stability was accomplished.

The overlap diagnostics of real GDP and real government expenditure, suggest that Keynesian theory holds, rather than Wagnerian assumptions. Government expenditure relatively predicts real GFCE, since in economic instability and downturns, government spending increased and ultimately resulted in a rise in GDP.

[5] The economic growth during 1980-2024 was far lower than the population growth rate
[6] Structural inefficiencies excluded the majority of the population from economic and labour force participation.

Figure 3:Total GDP output in South Africa (1960-2024)



Source 3: Author's computation

The overlap diagnostics of real GDP and real government expenditure, suggest that Keynesian theory holds, rather than Wagnerian assumptions. Government expenditure relatively predicts real GDP, since in economic instability and downturns, government spending increased and ultimately resulted in a rise in GDP. However, the retaliation by fiscal consolidations and economic shocks to promote GDP in turned resulted in a change in government expenditure, so there is probable cause that Wagner's theory holds. Nonetheless, Keynesian processes are suggested by deliberate budgetary stimulation during downturns. Therefore, it is crucial to distinguish between these consequences in order to develop fiscal policies that are both rational and sustainable.

5. Data and Methodology

Annual observations from 1960-2024 of the real GDP and government final consumption expenditure were obtained from the World Bank's Development Indicators. The series are valued at constant 2015 prices and in local currency (Rand). The data series was then transformed into natural logarithms to stabilize variance and to allow the interpretation of the elasticity coefficient.

Table 1: Descriptive statistics

Variable	Mean	Std. deviation	Min	Max
$\boldsymbol{GDP_t}$ *	2681.72	1187.52	837.1190000	4659.29
$\boldsymbol{GFCE_t}$*	489.1158950	253.9611371	98.7780000	918.2770597
$\boldsymbol{\log(GDP_t)}$**	28.5107764	0.4821850	27.4532321	29.1698850
$\boldsymbol{\log(GFCE_t)}$**	26.7491454	0.6262632	25.3161407	27.5457650

* defines variable in billions of Rand and ** defines for natural log

Source 4: Author's computation

In this report the independent variable will initially defined by real GDP and real government expenditure being the dependent variable. We acknowledge that some studies use real GDP per capita as an input and government expenditure as the output, to accurately apply Wagner's Law in terms of the assumptions on economic development being that as per capita income increases the demand for public goods increase. Prominently most of the results will be employed towards the natural log of real GDP and government spending, however after the initial hypothesis a robustness check will be done to determine any deviation[7] of the effect of Wagner's Law in regards to real GDP and real GDP per capita[8].

We firstly applied the stationarity test, by use of the Augmented Dicky-Fuller (ADF) test, to each of the series. Within the ADF test we included a constant and one lag of the dependent variable. For $\log(GDP_t)$, the test statistic was $\tau = -3.08$ with a p – value $= 0.0331$ (Table 2). For $\log(GFCE_t)$ a test statistic of $\tau = -4.37$ and a p-value of 0.0008 was returned (Table 2). Thus, the test indicated that both series are stationary at level, implying that the null hypothesis of a unit root is rejected at a 5% significance level. A further analysis by differencing or cointegration was however not necessary, due to the stationarity.

Moreover, $\tau = -1.022$ and $p - value = 0.737$ was determined for $\log(GDP_t^{pc})$ and for the variable $\log(GFCE_t)$, $\tau = 1.414$ and p – value $= 0.56$. It therefore implies that the variables are non – stationary at levels, however to account for this a VAR model was incorporated to address autocorrelation and lagged dynamics (*Appendix II*).

Table 2: Augmented Dickie-Fuller (ADF) test

Variable	Model type	τ	p-value
$\boldsymbol{\log(GDP_t)}$	Single mean	-3.0798	0.0331*
$\boldsymbol{\log(GFCE_t)}$	Single mean	-4.3700	0.0008*

* defines variable that is stationary at level on a 5% significance level

Source 5: Author's computation

Following the ADF test, we modelled an OLS regression model that indicated that there are autocorrelated residuals, as indicated by the Durban Watson statistic and $\hat{\rho} = 0.923$ (Table 3). This suggested a positive autocorrelation that is present within the residuals, such that there was an additional estimation through a Generalized Least Squares (GLS) model using a SAS PROC AUTOREG procedure with nlag=1. This method provided unbiased estimates for

[7] It is to note that the period range differences from the initial assessment i.e. the relationship between real GDP per capita and government spending has a period range of 1980-2024, hence there is deviations from the original series in descriptive statistics.

[8] The hypothesis test in regards to real government expenditure as a function of real GDP per capita will however be noted in the discussion and result, as well as any deviation, but the results will only be shown within the appendix.

β_1 (elasticity coefficient) and $\hat{\rho}$ (autocorrelation parameter).Similarly for real GDP per capita, the OLS model indicated $\hat{\rho} = 0.858$ and a Durban Watson statistic of 0.077.

A bivariate VAR model of order two was executed to determine the dynamic interactions between GDP and GFCE. With the assessment, the model included two lags of both $\log(GDP_t)$ and $\log(GFCE_t)$, to allow for dynamic interactions over time. The VAR (2) model is expressed as:

Equation 3: VAR Granger causality expression

$$\begin{bmatrix} \log(GDP_t) \\ \log(GFCE_t) \end{bmatrix} = \gamma_0 + \phi_1 \begin{bmatrix} \log(GDP_{t-1}) \\ \log(GFCE_{t-1}) \end{bmatrix} + \phi_2 \begin{bmatrix} \log(GDP_{t-2}) \\ \log(GFCE_{t-2}) \end{bmatrix} + \varepsilon_t$$

where γ_0 is the intercept vector, ϕ_1 and ϕ_2 are coefficient matrices for lagged values, and ε_t is a vector of error terms.

Wald tests were applied to examine whether lagged values of GFCE significantly improve the prediction of GDP and vice versa. The Wald tests were on exclusion of the GFCE lags from the GDP equation and vice versa yielded χ^2 statistics whose significance indicates Granger causality.

The results revealed that lagged GFCE values significantly predict current GDP, while lagged GDP values do not significantly predict GFCE. Concurrently, real GDP per capita does not granger cause government spending, however the converse is true. This indicates that changes in public expenditure have a statistically significant impact on future output levels, supporting the Keynesian hypothesis that fiscal policy can drive economic growth. Meanwhile, the lack of predictive power from GDP to GFCE suggests that Wagner's Law may be reflected more in long-term proportional trends rather than short-term causality. This distinction underlines the complexity of the fiscal-growth relationship and the importance of distinguishing between correlation, elasticity, and causality.

6. Results and discussion

The elasticity estimate $\beta_1 = 1.196$, yielded by the GLS regression, implies that a 1 percent increase in GDP is associated with an approximate 1.20 percent increase in government consumption (Table 3).

Table 3: Elasticity estimation - OLS v GLS Regression results

Model	Intercept	β_1 (log_GDP)	Std. Error	R^2	Durban Watson statistic	Autocorrelation ρ
OLS	-9.87582	1.28460	0.02413	0.9783	0.140	0.923
GLS	-7.3581	1.1955	0.0644	0.9971	1.5553	AR (1) corrected

Source 6: Author's computation

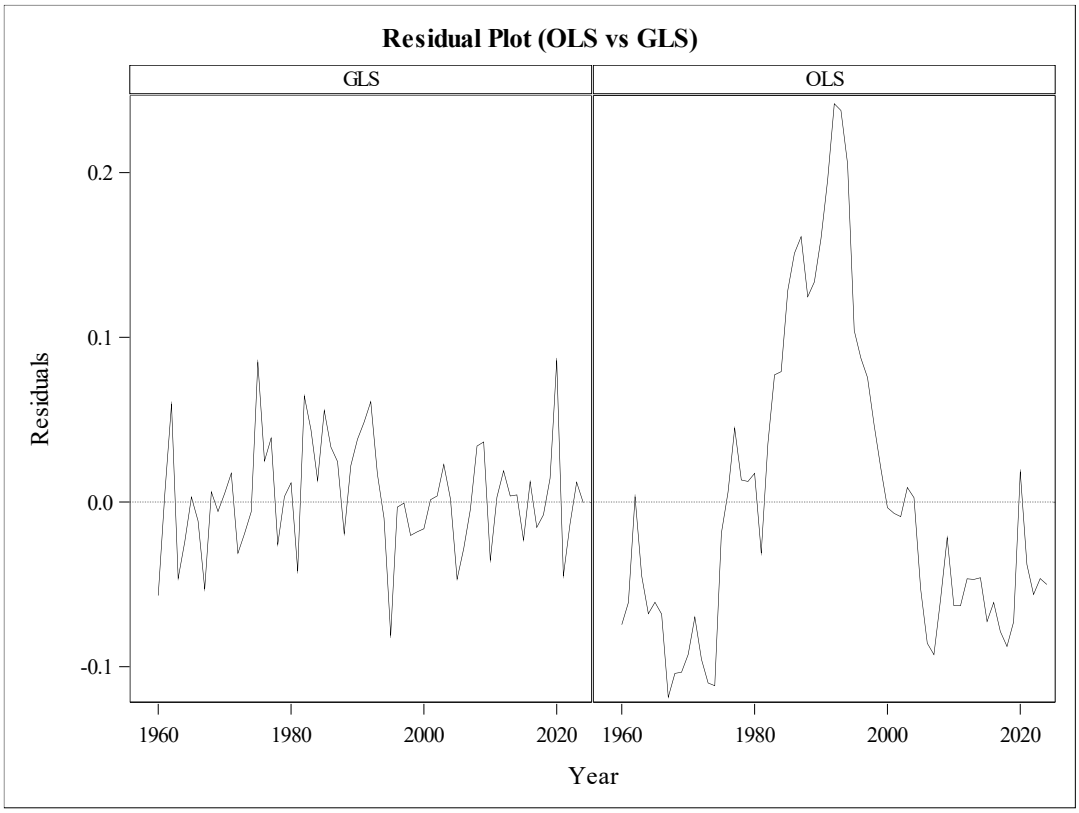
Since $\beta_1 = 1.1955 > 1$, Wagner's Hypothesis is strongly supported by the data, hence there is a high-income elasticity for public goods such as education, health and public infrastructure for a higher societal welfare development – which is highly evident in the country's fiscal allocations. Moreover for sequential assessment $\beta_1 = 0.8331 < 1$ regarding real GDP per capita, Wagner's Hypothesis does not hold (*Appendix III*).

Further on both the OLS and GLS models returned a highly adjusted R^2 indicator with 97.83% and 99.71% variation within the model. Therefore the model is a sufficient representation of the inductive assumption that government expenditure has an effect on the economic growth within South Africa. In terms of real GDP per capita the OLS model returned a $R^2 = 0.5167$, meaning that real GDP per capita does not generally explain the variation in government spending. However, correcting for autocorrelations the GLS model produced and $R^2 = 0.9614$, implying that 96.14% of the variation is explained by the model (*Appendix III*).

Later we will discuss the assumptions of the current events in the country that can be a misleading assumption on the model - this is evident in the high efficiency in the model since highly compound R^2 indicators may be overstated in the generalization of the hypothesis. In the OLS model the R^2 was sufficient to produce an effective estimate however when the methodology reverted towards a GLS model, the R^2 value increased significantly Although this is relatively the norm in error minimization it significantly effects the variation.

After correcting for autocorrelation, the Durbin Watson statistic improved to 1.56, which confirms the serial correlation has effectively been addressed (**Error! Reference source not found.**). Likewise, for real GDP per capita, the Durban Watson statistic improved form 0.077 to 0.6909, such that the autocorrelation has effectively been addressed (*Appendix III* ; Appendix V).

Figure 4: Residual diagnostics for autocorrelation correction



Source 7: Author's computation

Considering the Granger causality test, GDP does not Granger cause GFCE. This suggest that endogenous income rises do not predict the spending changes beyond contemporaneous correlation. However, the Keynesian axiom is supported by the causality test. GFCE

significantly Granger causes GDP, such that government spending serves as a catalyst of subsequent economic activity.

Table 4: Granger causality Wald Test Results

Casual Direction	Chi-square statistic (χ^2)	Degrees of freedom	p-value
log_GDP→log_GFCE	3.22	2	0.2002**
log_GFCE→log_GDP	12.58	0.0019	2*

**Granger causality rejected at 5% significance level
*Significant granger cause

Source 8: Author's computation

7. Policy considerations

Fiscal policy must strike a balance between short-term stabilisation and long-term structural spending growth in order to reconcile both Wagnerian and Keynesian views.

The strong elasticity estimate indicates a compound growth, such that without corrective action government spending will inevitably outpace revenue growth, by Wagner's perspective. To preserve the fiscal balance, fiscal regulators and authoritarians should broaden the tax base, through efficient VAT compliance methods. Furthermore, the government should rationalize in tax expenditures and curbing illicit financial flows. A further revenue mobilization solution is the adjustment of earmarked levies for infrastructure or environmental remediation. In addition to the mobilization, there must be emphasis with regards to spending. The medium-term expenditure frameworks (MTEF) should incorporate zero-based reviews of major budget votes as well as a requirement cost benefit analysis and justifications for new program expansions as well as a hard ceiling on the compensation of employees since the aforementioned absorbs a large and growing share of the government final consumption expenditure.

From a Keynesian view, during periods of negative economic growth, automatic stabilizers such as social grants and unemployment benefits play a crucial role in mitigating demand fluctuations. In downturns regulatory authorities can augment these automatic stabilizers with targeted increases with regards to the public sector hiring, temporary tax relief for small businesses or an accelerated payment cycle to service providers. Further empirical studies suggested that the fiscal multiplier exceeds one during recessions in South Africa. This indicates that policies can be highly effective if properly targeted by deploying an increase in public expenditure, predominantly within labour intensive public employment. A simultaneous cause will be a rise in aggregate demand as well as address infrastructure blockages. However, the interventions must be carefully calibrated to avoid exceeding the debt-to-GDP ratio or crowding out private investment in the recovery phase.

Furthermore, the structural reforms pertaining to performance-based budgeting can improve efficiency in public spending. The approach allows for an effective allocation of funds based on outcome orientated budgeting rather than the clear and concise services and delivery targets. This ultimately incentivizes departments to achieve real results rather than simply spending allocated funds. Additionally institutional investors can be attracted by the implementation of blended finance instruments such as social or green bonds and through public – private partnerships, which will allow for co-funded social and environmentally beneficial initiatives.

It therefore may follow by integrating the considerations into the medium-term budget policy statement South Africa can align its fiscal trajectory with both Wagner's hypothesis and the Keynesian assertions such that there will be insurance that public expenditure growth remains sustainable, efficient, and supports long run economic prosperity.

8. Conclusion

This study provides empirical support for Wagner's Law in South Africa over the period 1960 to 2024. The elasticity coefficient exceeding one indicates that public expenditure rises more than proportionally with the income. Concurrently, the Granger causality analysis reflects that government spending drives GDP, further validating Keynesian principles. The elasticity evidence of Wagner's and causality evidence of the Keynesian's assertions calls for integrated fiscal strategies that accommodate long term expenditure growth and leverage public expenditure to stabilize and stimulate economic growth. While this paper provides a basis of Wagner's Law, one must refer to practicality regarding institutional deficiencies such as corruption within South Africa since it may overstate the actual government spending of the economy. Wagner's Law may be experimentally supported by South Africa's elasticity coefficient, but the country's status as a developing economy suggests that a proportionate increase in public spending may not always indicate effective, welfare-enhancing expansion. Rather, the pure Wagnerian mechanism may be distorted by structural inefficiencies, fiscal rigidity, and governance instability.

9. References

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10. Appendix

Appendix I:Descriptive statistics for real GDP per capita and GFCE (1980-2024)

Variable	Mean	Std. deviation	Min	Max
GDP_t^{pc} **	69714	7046.03	58434.02	79760.68
$GFCE_t$*	618.8054706	189.6066139	338.3640000	918.2770597
$\log(GDP_t^{pc})$***	11.1471195	0.1017429	10.9756535	11.2867860
$\log(GFCE_t)$****	27.1043416	0.3107733	26.5473881	27.5457650

* ,**,***defines variable in billions of Rand, in thousand of Rand and natural log respectively

Source 9: Author's computation

Appendix II: Augmented Dicky-Fuller (ADF) test

Variable	Model type	τ	p-value
$\log(GDP_t^{pc})$	Single mean	-1.0216	0.7373*
$\log(GFCE_t)$	Single mean	1.4135	0.5670*

* defines variable that is stationary at level on a 5% significance level

Source 10: Author's computation

Appendix III:Elasticity estimation - OLS v GLS Regression results

Model	Intercept	β_1	Std. Error	R^2	Durban Watson statistic	Autocorrelation ρ
OLS	2.62966	2.19561	0.32383	0.5167	0.077	0.858
GLS	2.6297	0.8331	0.3373	0.9614	0.6909	AR (1) corrected

Source 11: Author's computation

Appendix IV:: Granger causality Wald Test Results

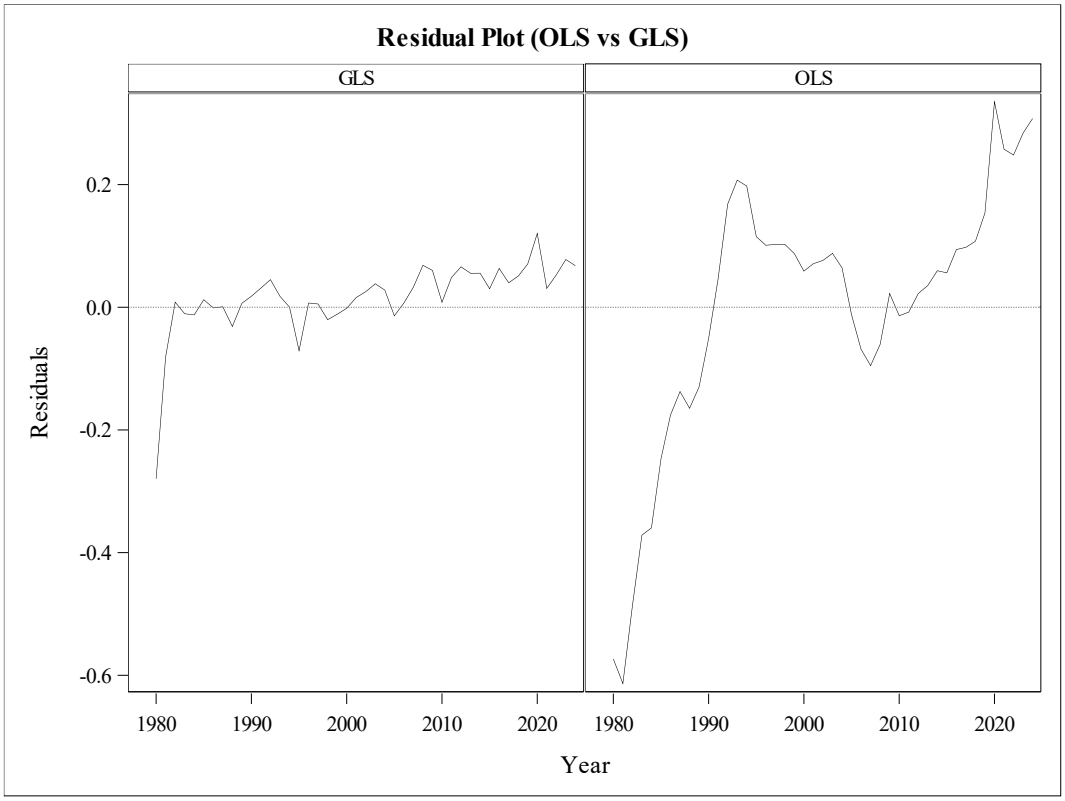
Casual Direction	Chi-square statistic (χ^2)	Degrees of freedom	p-value
log_GDP^{pc}→log_GFCE	4.16	2	0.1249**
log_GFCE→log_GDP	7.33	1	0.0068*

**Granger causality rejected at 5% significance level

*Significant granger cause

Source 12:Author's computation

Appendix V: Residual diagnostics for autocorrelation correction



Source 13: Author's computation

[1] ***This paper is part of an independent personal research project undertaken voluntarily by the author. The analysis has not undergone formal peer review. Scholarly feedback and collaborative peer review are welcomed.***