

Inflation Co-Movement Dynamics in SADC: A Continuous Wavelet Analysis

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Abstract

This study examines the co-movement dynamics of inflation rates among Southern African Development Community (SADC) member countries using continuous wavelet analysis. The main objective is to determine if and how inflation rates are synchronized across these countries, identifying potential structural frequency breaks, testing co-movement clusters, and assessing the influence of common factors. Monthly Consumer Price Index (CPI) data from 16 SADC countries, covering the period from January 1990 to October 2025, are analyzed using wavelet coherence and phase difference analysis. The results reveal marked heterogeneity in inflationary integration. A core of strong integration, including South Africa, Botswana, and Lesotho, exhibits high and persistent coherence across all frequencies, reflecting close synchronization of inflationary shocks. A group of moderately integrated countries, including Malawi and Zambia, shows significant coherence, primarily in the medium and long term. In contrast, Madagascar and Tanzania appear largely disconnected from regional inflationary dynamics, exhibiting weak and erratic coherence.

Keywords

Inflation, Co-Movement Dynamics, SADC, Wavelet

1. Introduction

Do inflation rates co-move together within the context of SADC member countries? How are inflation rates synchronized within SADC member countries?

This paper tests how inflation rates in SADC member countries are synchronized. The literature on inflation co-movement fluctuation across countries has been growing from the perspective of academic researchers. For instance, Ciccarelli and Mojon (2010) have argued that a common factor could explain, on

average, up to 70 percent of consumer price index (CPI) variation in countries. Similarly, [Neely and Rapach \(2008\)](#) posit that common and regional factors could explain 50 percent of the fluctuation in national inflation rates of countries. In a separate study, [Monacelli and Sala \(2009\)](#) found similar findings, and concluded that a common factor could account for about 15 - 30 percent of the variation in consumer prices.

Why SADC?

In fact, SADC sub-region has become an investment destination in recent years for many international firms. It is therefore important to examine whether inflation rates co-move across SADC countries, and alert individual investors, corporations, financial intermediaries, market makers, regulators, governments, etc on what they should expect when moving from one country to another.

The main objective of the present paper is to examine how inflation rates co-move across SADC countries.

Specific objectives are:

1) To map and analyze the **pairwise coherence and phase dynamics** of inflation rates across selected SADC countries **over time and across different frequencies**, identifying periods and frequency bands of strong synchronization.

2) To **identify and characterize potential clusters (or “clubs”)** of countries exhibiting similar co-movement patterns and degrees of integration;

To study the pair-wise co-variation in inflation rates for the selected countries at different

frequencies, and further determine the essence of different frequencies in explaining inflation co-variation in the selected countries. The adopted approach, wavelet analysis, has been used in recent times to study relationships between several macroeconomic variables in the economic literature (e.g., [Raihan et al. 2005](#); [Crowley & Mayes 2009](#); [Rua & Nunes 2009](#); [Aguiar-Conraria & Soares 2011](#); [Madaleno & Pinho, 2012](#); [Dar et al., 2013](#); [Tiwari et al., 2013a, 2013b, 2013c](#)), for example, business cycles ([Raihan et al., 2005](#)), business cycle co-movement and synchronization in the Euro area ([Crowley & Mayes, 2009](#)), co-movement in international stock markets ([Rua & Nunes, 2009](#)), oil price changes and the macroeconomy ([Aguiar-Conraria & Soares, 2011](#); [Tiwari et al., 2013b](#)), price shock transmission in stock markets ([Madaleno & Pinho, 2012](#)), interest rates and share prices, producer price index and consumer price index ([Tiwari et al., 2013c](#)), and inflation synchronization among G7 economies ([Tiwari et al., 2015](#)).

The contributions of the current study can be seen from four perspectives:

1) We test whether there are some co-movements between inflation rates within SADC. We rely on continuous wavelet approach;

2) We detect the co-movement dynamics in pairs of countries;

3) The SADC region is concerned with our investigations since significant transformations have recently taken place in this region, electing this region for more scrutiny.

The rest of the paper is organized as follows: in Section 2, a brief literature re-

view is provided. It is followed by Section 3, which is related to the data and empirical methodology. Results appear in Section 4. It is followed by a discussion in Section 5. Section 6 concludes the paper.

2. Related Literature Review

We now turn to the related literature review with the goal of emphasizing research gaps.

2.1. The Existence of Co-Movements

The prior literature on inflation co-movement is rare and very limited since most studies use different models to assess co-movement of inflation rates (e.g., see [Kose et al., 2003, 2008](#)). Other studies are based on dynamic latent factor models in order to examine international co-movements in real macroeconomies. This is different from the study of [Wang and Wen \(2007\)](#) whether co-movement in inflation rates is tested. The authors concluded that co-movement in inflation is higher than in other variables using the calibrated New Keynesian two-country models. [Mumtaz et al. \(2011\)](#), using factor model, decomposed sectorial national inflation rates into world and national components and reached the same result as [Mumtaz et al. \(2011\)](#). [Monacelli and Sala \(2009\)](#) illustrated the fact that international spillovers of inflation are weak and, therefore, cannot be considered as attributes of inflation co-movement. [Bernanke \(2007\)](#) concluded that trade channel inflation co-movement can increase and decrease import prices, and, thus, serves an indirect pro-competitive effect, which reduces the pricing power of domestic firms (e.g., see [Bernanke 2007](#)).

In sum, no consensus exists as to how inflation co-moves across countries.

2.2. Domestic Inflation and Attitude of the Central Bank

Another strand of the literature focuses on domestic inflation and its link with the central bank. In fact, domestic inflation is greater in countries that have a greater dependency on central banks, mainly due to common inflation factors (e.g., see [Neely & Rapach 2008](#)). A study by [Neely and Rapach \(2008\)](#) indicated that world and regional factors are the main factors that explain inflation variability across 64 countries. Again, taking a cue from [Beck et al.'s \(2009\)](#) study, “Euro-area effects” accounts for variation in the prices of regional economies. However, [Eickmeier and Moll \(2009\)](#) follow a different approach by estimating factor-augmented Phillips curves for 24 OECD economies.

In fact, the method used to test whether there is a link between inflation rates and central bank interbank loan see ambiguous.

2.3. Common Factors

Several common factors drive co-movements in inflation. A study by [Ciccarelli and Mojon \(2010\)](#) suggested that, on average, close to 70% of the variation in a country’s inflation can be explained by a common factor. However, the empirical evidence using different methodologies provides mixed evidence on inflation co-

movement in different countries.

While the link between inflation and common factors has been extensively studied using formal methods such as dynamic factor models (e.g., [Ciccarelli & Mojon, 2010](#); [Neely & Rapach, 2008](#)), these approaches typically assess average co-movement over time. The continuous wavelet coherence analysis employed in this study offers a complementary, novel perspective by allowing us to examine this relationship in the time-frequency domain. This enables the identification of *when* and *at which cyclical frequencies* (short, medium, or long-term) inflationary shocks become synchronized, providing a more dynamic and granular understanding of co-movement patterns in the SADC region.

3. Data and Econometric Methodology

We begin with data sources.

3.1. Data Sources

To conduct this study, we rely on monthly consumer price indexes (CPI) of SADC member countries. The 16 member countries of the Southern African Development Community (SADC) are Angola, Botswana, Comoros, the Democratic Republic of the Congo, Eswatini, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Tanzania, Zambia, and Zimbabwe. Data (consumer price indexes, CPI) are obtained from DataStream for the period of January 1990 to October 2025, and considered for the construction of the inflation variable. The CPI is used to construct the inflation rate of these countries. We chose 16 SADC because they represent a group from diverse regions of SADC with: 1) different histories; 2) active or inactive financial markets; 3) strong and weak institutions; 4) significant transformations that have taken place recently in SADC.

3.2. Econometric Methodology

Next, we develop the continuous wavelet methodology used to analyze co-movements between inflation rates in SADC.

Continuous wavelet

The wavelet transform approach is attractive as it decomposes signals into dilated and translated functions referred to as mother wavelets $u(t)$. The wavelet has a mother.

The mother wavelet is expressed as a function of two constructs, where one focuses on time position (s) , with the other parameter focusing on the scale of the wavelets. Hence, a time series $x(t)$ that has been subjected to the wavelet transform decomposition with reference to the selected mother wavelet is described in Equation (1):

$$W_x(a, \tau) = \frac{1}{\sqrt{a}} \int_{-\infty}^{+\infty} x(t) \varphi^* \left(\frac{t - \tau}{a} \right) dt = \int_{-\infty}^{+\infty} x(t) \varphi_{a,\tau}^*(t) dt \quad (1)$$

Here, $W_x(a, \tau)$ denotes the influence of the scales, whereas $*$ denotes the influence of the complex conjugate form leading to a two-dimensional surface denoted as $R(W_x(a, \tau))$.

Mallat (1998) posits that the best methodology to consider in examining quantitative information about phase connections that exist between two time series is continuous and complex wavelets. In the literature, the two most referenced continuous wavelets are the “Mexican hat” and the “Morlet wavelet”. High frequency resolution is associated with the Morlet wavelet, since its scales and frequencies are highly localized. However, in the case of the Mexican hat, frequency localization is poor, but it has good time localization.

In this paper, the Morlet wavelet is adopted for the purposes of the study:

$$\varphi(t) = \pi^{-1/4} \exp(-i2\pi f_0 t) \exp(-t/2^2) \quad (2)$$

Under the Morlet wavelet, the nexus amid the wavelet scale and the frequency is outlined below $\frac{1}{f} = \frac{4\pi a}{w_0 + \sqrt{2 + w_0^2}}$ with w_0 about 2π .

For the Morlet wavelet, the studied signal is separated into phase and amplitude, since it can be factored into an imaginary and a real part. We write a complex wavelet coefficient $W_x(a, \tau)$, with reference to its phase $\varphi_x(a, \tau)$ and modulus $|W_x(a, \tau)|$.

We discretized Equation (1) for time series $\{x_n : n = 1, \dots, N\}$ for practical purposes, as shown below:

$$W_x^n(a, t) = \frac{\delta t}{\sqrt{a}} \sum_{n=0}^{N-1} x_n \varphi^* \left((m-n) \frac{\delta t}{a} \right), \quad m = 1, 2, \dots, N-1 \quad (3)$$

From Equation (3), δt denotes the uniform step size. Following Torrence and Compo (1998), we explored the expediency presented discrete Fourier transform by discretizing the wavelet transform, as presented below:

$$W_x^n(a, t) = \frac{\delta t}{\sqrt{a}} \hat{x}_n \varphi^*(aw_m) e^{i w k n \delta t}, \quad m = 0, 1, 2, \dots, N-1 \quad (4)$$

A set of scales necessary for use in the wavelet transform was obtained using the formula below:

$$a_j = a_0 2^{j\delta t}, \quad j = 0, 1, \dots, J$$

where $J = \delta j^{-1} \log_2(N\delta t/a_0)$. a_0 denotes the least resolvable scales which is chosen to ensure that the corresponding Fourier period is about $2\delta t$.

Wavelet power spectrum, Wavelet coherency, and Phase difference

Our first important measure to consider is the localized wavelet power spectrum as:

$$S_x(f, \tau) = \|W(f, \tau)\|^2 \quad (5)$$

The localized wavelet power spectrum in the time-frequency space shows how the power or intensity of oscillations in a time series changes over both time and frequency (or scale).

Our second important measures are the wavelet cross spectrum and the wavelet coherence to compute the relation amid the two time series that are non-stationary.

The wavelet cross-spectrum used in this paper is defined as:

$$W_{x,y}(f, \tau) = W_x(f, \tau)W_y^*(f, \tau) \quad (6)$$

The wavelet cross-spectrum is used to analyze the relationship between two time series in the time-frequency domain, identifying where and when they are correlated.

The wavelet coherency is defined as,

$$R_{x,y}(f, \tau) = \frac{\|\langle W_{x,y}(f, \tau) \rangle\|}{\|\langle W_{x,x}(f, \tau) \rangle\|^{1/2} \|\langle W_{y,y}(f, \tau) \rangle\|^{1/2}} \quad (7)$$

where $\langle \rangle$ represents a smoothing operator in both scale and time. $R_{x,y}(f, \tau)$ is restricted by $0 \leq R_{x,y}(f, \tau) \leq 1$. The wavelet coherency measures the localized correlation between two or more time series in the time-frequency domain.

We also compute the wavelet phase function $\phi_{x,y}(f, \tau)$,

$$\phi_{x,y}(f, \tau) = \tan^{-1} \frac{\text{Im}(\langle W_{x,y}(f, \tau) \rangle)}{\text{Re}(\langle W_{x,y}(f, \tau) \rangle)} \quad (8)$$

where, $\text{Im}(\cdot)$ is the imaginary part of the number while $\text{Re}(\cdot)$ is the real part.

Based on the phase difference, we determine the possible linkages existing in the two series both in phase and out of phase. Monte Carlo approaches are then used to test whether the wavelet patterns displayed by the wavelet approach are statistically significant.

4. Empirical Results

This section presents and discusses the results of wavelet analysis, which aims to examine the co-movements of inflation between selected SADC countries. For each pair of countries, we analyze wavelet consistency and phase difference to identify periods of strong correlation and causal relationships.

We present below the detailed analysis for all pairs of countries, grouped by reference country.

4.1. Pairs Implying Botswana

Botswana-Lesotho (**Figure 1**): Strong and persistent coherence over most of the period and for medium to low frequencies (10 to 60 months). The series are in phase, indicating significant and contemporaneous synchronization of inflation cycles.

Botswana-Madagascar (**Figure 2**): Moderate and sporadic coherence, mainly in the medium frequency band (20 to 40 months). The phase difference is variable, suggesting an unstable co-movement relationship.

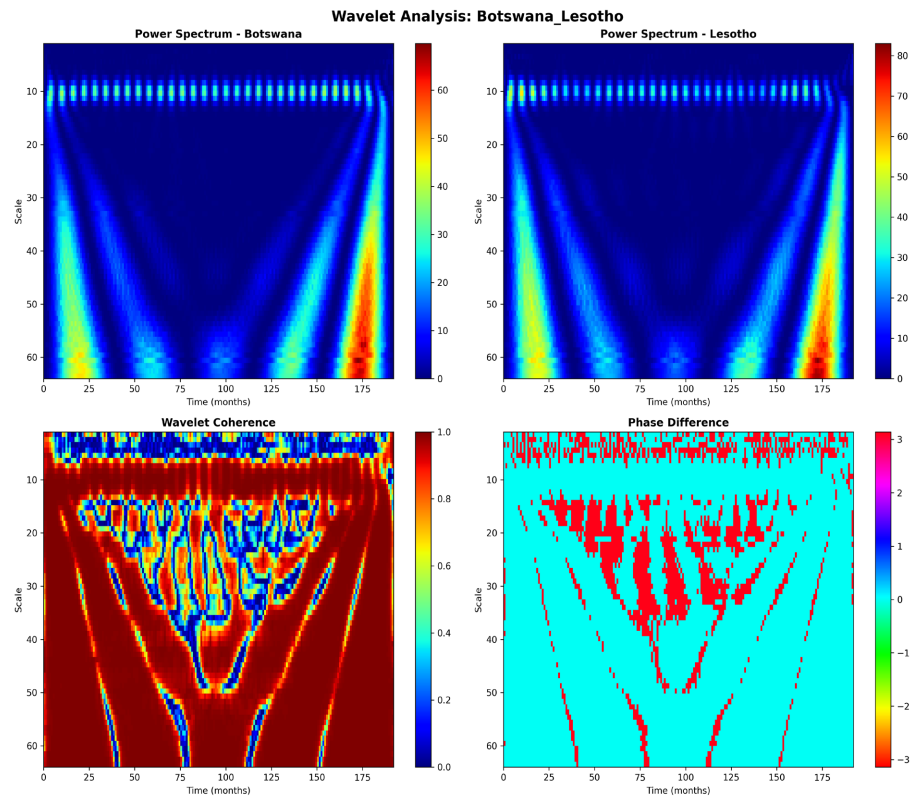


Figure 1. Wavelet analysis: Botswana-Lesotho.

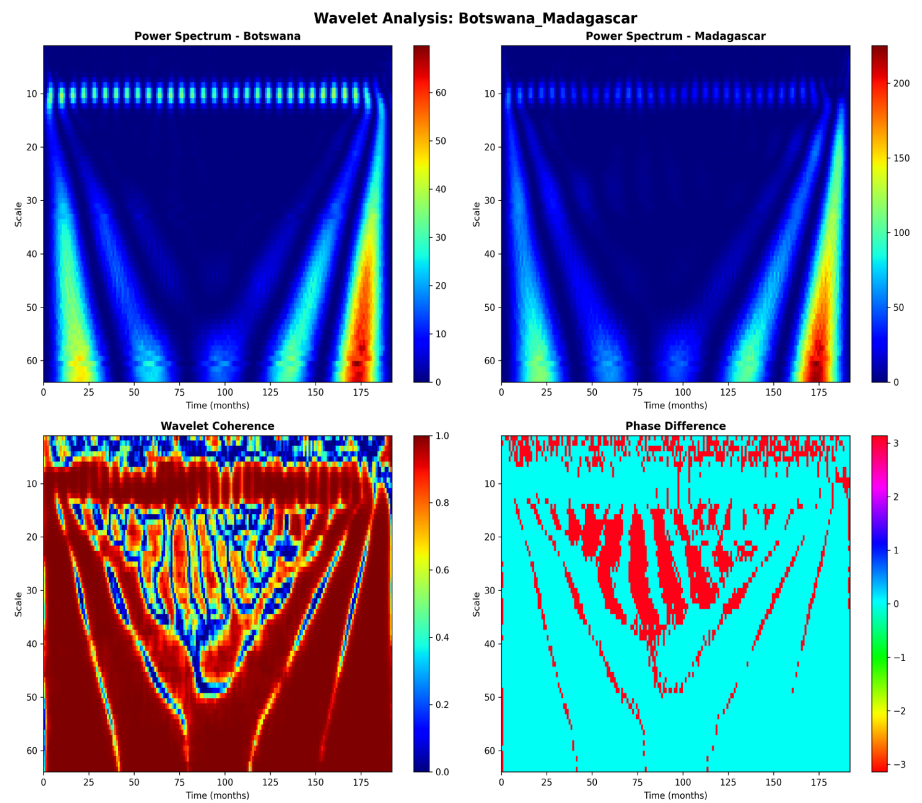


Figure 2. Wavelet analysis: Botswana-Madagascar.

Botswana-Malawi (**Figure 3**): Strong coherence at medium and low frequencies. The series are in phase over most periods of high coherence, indicating strong medium- and long-term synchronization.

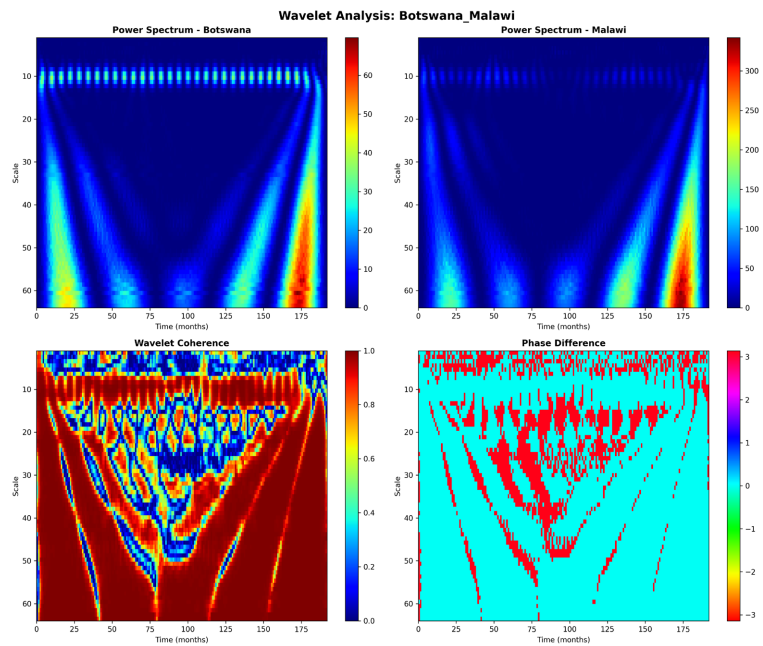


Figure 3. Wavelet analysis: Botswana-Malawi.

Botswana-South Africa (**Figure 4**): Very strong coherence over almost the entire period and for all frequencies. The series are in phase, confirming strong contemporaneous synchronization, reflecting regional economic integration.

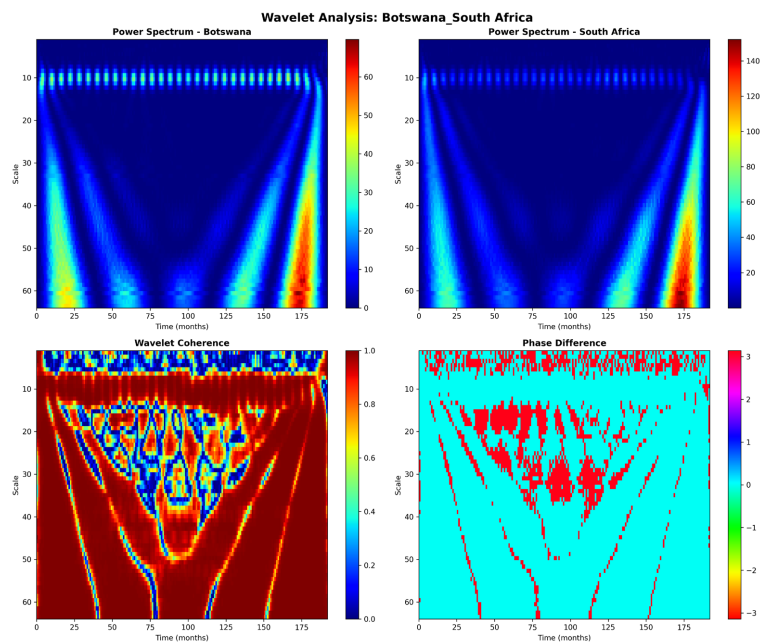


Figure 4. Wavelet analysis: Botswana-South Africa.

Botswana-Tanzania (**Figure 5**): Weak coherence over the entire period. A few pockets of coherence appear at very low frequencies (long term) towards the end of the period. The phase difference is erratic, confirming the absence of significant co-movements.

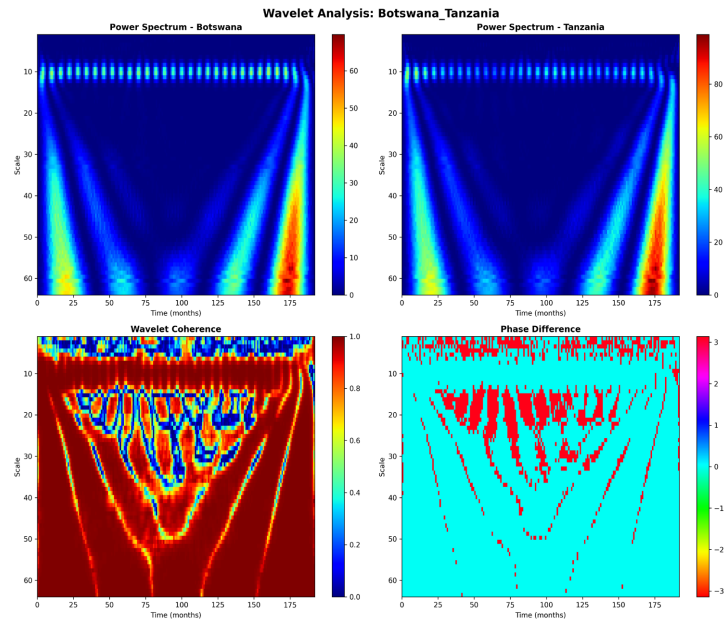


Figure 5. Wavelet analysis: Botswana-Tanzania.

Botswana-Zambia (**Figure 6**): Moderate to strong coherence at mid and low frequencies, particularly in the second half of the period. The phase difference is relatively stable and in phase, suggesting increasing synchronization.

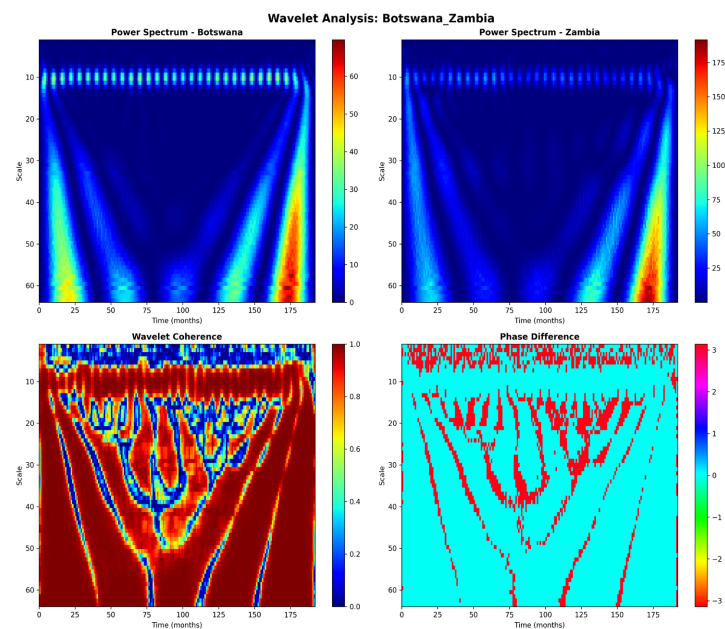


Figure 6. Wavelet analysis: Botswana-Zambia.

4.2. Pairs Implying Lesotho (Outside Botswana)

Lesotho-Madagascar (Figure 7): Weak and sporadic coherence, mainly limited to mid and low frequencies at the beginning of the period. The phase difference is unstable, indicating a weak relationship.

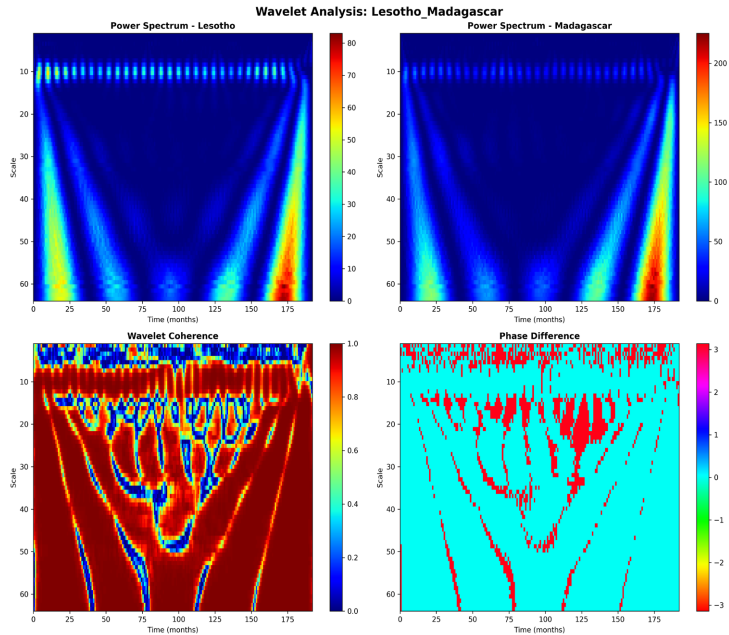


Figure 7. Wavelet analysis: Lesotho-Madagascar.

Lesotho-Malawi (Figure 8): Strong coherence at mid and low frequencies. The series is in phase, indicating significant synchronization.

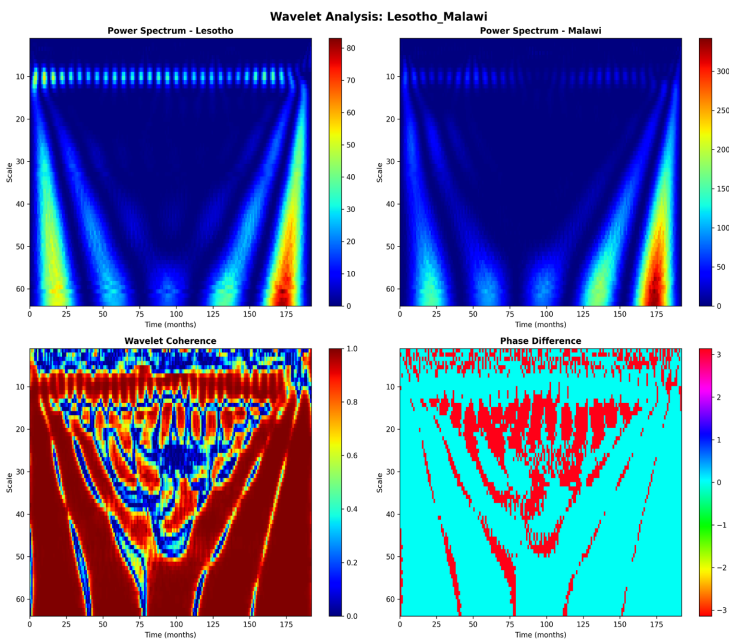


Figure 8. Wavelet analysis: Lesotho-Malawi.

Lesotho-South Africa (**Figure 9**): Very strong coherence over almost the entire period and for all frequencies. The series is in phase, confirming very strong integration.

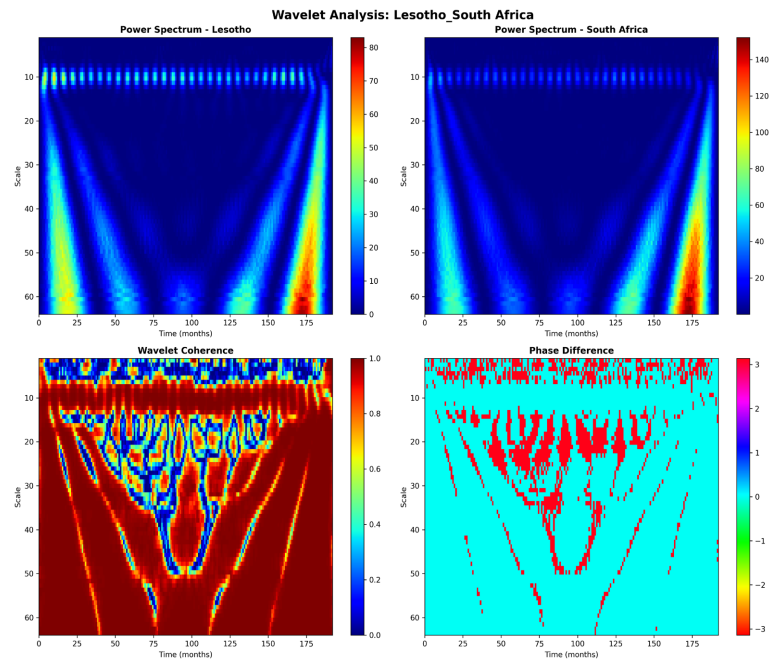


Figure 9. Wavelet analysis: Lesotho-South-Africa.

Lesotho-Tanzania (**Figure 10**): Weak coherence over the entire period. The phase difference is erratic.

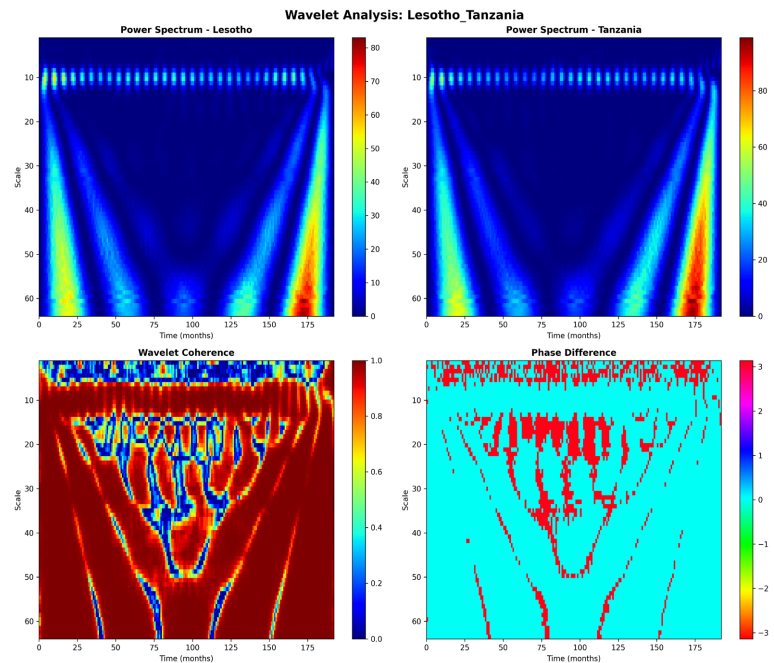


Figure 10. Wavelet analysis: Lesotho-Tanzania.

Lesotho-Zambia (**Figure 11**): Moderate coherence at mid and low frequencies. The series is in phase in areas of strong coherence.

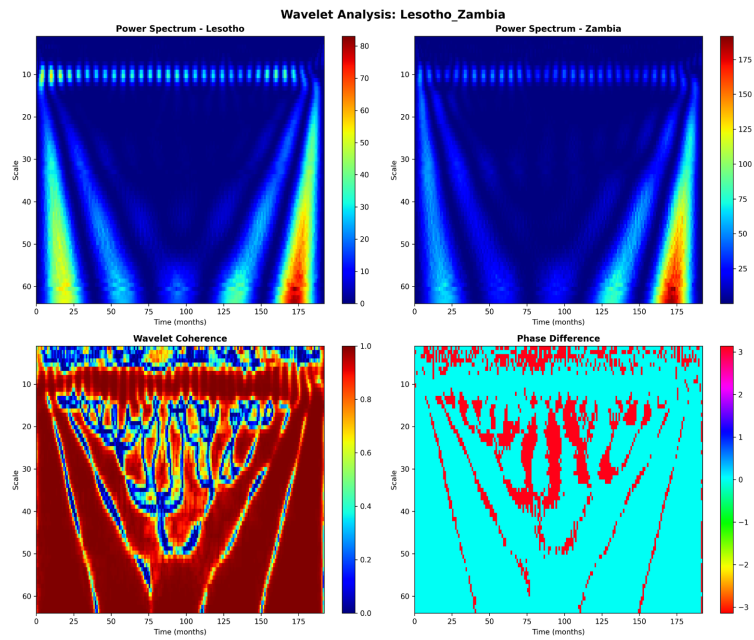


Figure 11. Wavelet analysis: Lesotho-Zambia.

4.3. Pairs Implying Madagascar (Outside Botswana and Lesotho)

Madagascar-Malawi (**Figure 12**): Moderate coherence, mainly in the mid-frequency band. The series are in phase, indicating some medium-term synchronization.

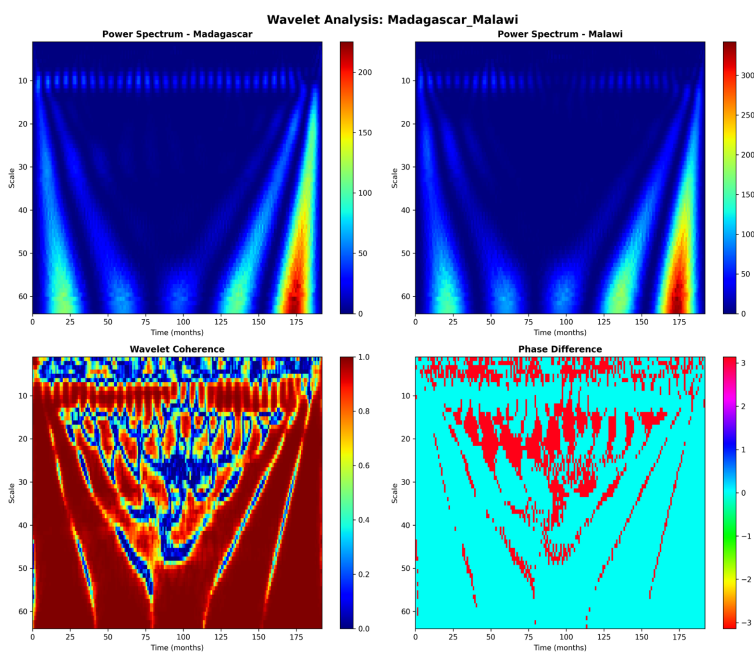


Figure 12. Wavelet analysis: Madagascar-Malawi.

Madagascar-South Africa (**Figure 13**): Weak coherence, limited to mid-frequencies at the beginning of the period. The phase difference is unstable, suggesting a weak influence.

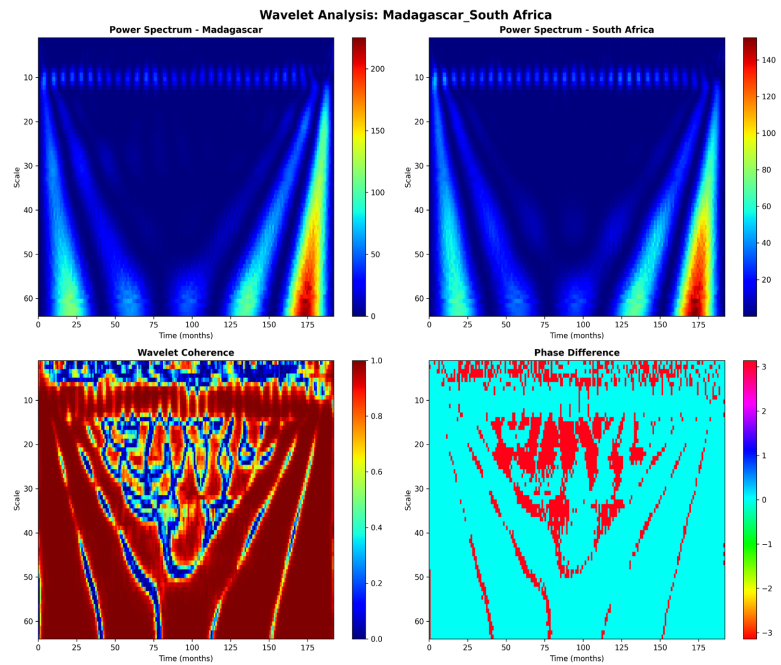


Figure 13. Wavelet analysis: Madagascar-South-Africa.

Madagascar-Tanzania (**Figure 14**): Very weak coherence over the entire period. The phase difference is erratic, confirming a disconnection.

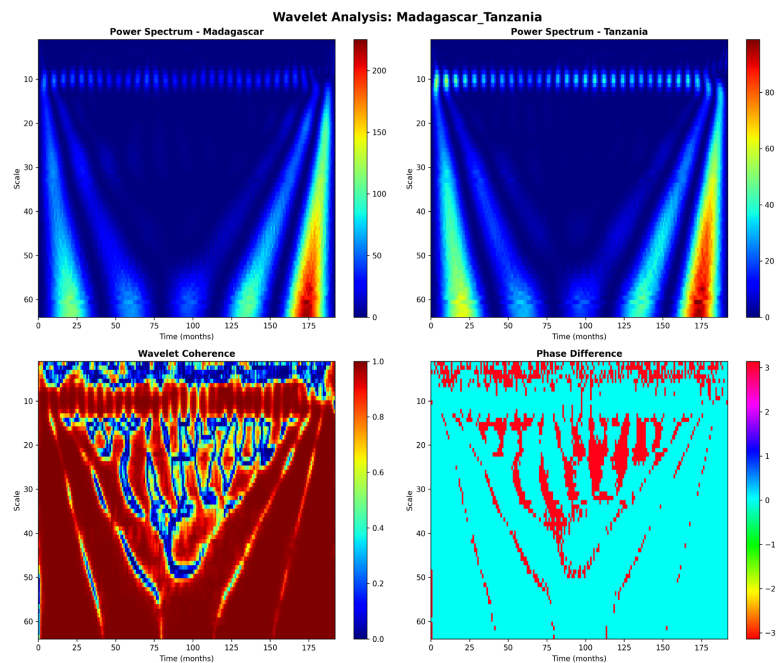


Figure 14. Wavelet analysis: Madagascar-Tanzania.

Madagascar-Zambia (**Figure 15**): Moderate coherence in the mid and low frequencies. The series is in phase in areas of strong coherence.

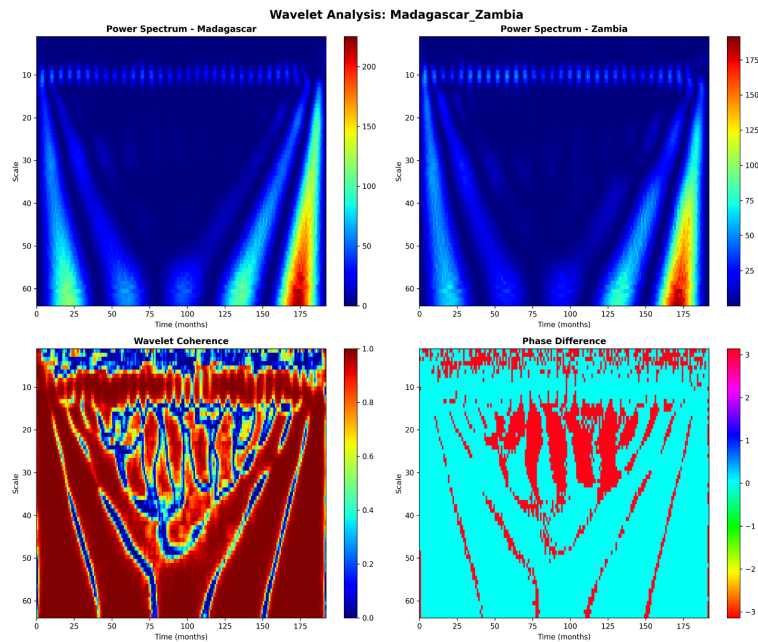


Figure 15. Wavelet analysis: Madagascar-Zambia.

4.4. Pairs Implying Malawi (Hors Botswana, Lesotho and Madagascar)

Malawi-South Africa (**Figure 16**): Strong coherence in the mid and low frequencies. The series is in phase, indicating significant synchronization.

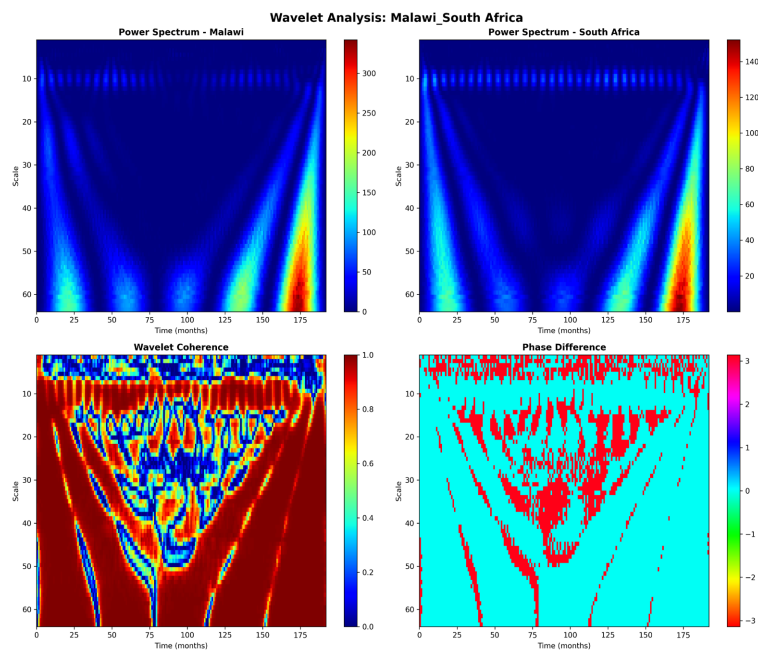


Figure 16. Wavelet analysis: Malawi-South-Africa.

Malawi-Tanzania (**Figure 17**): Moderate to strong coherence in the mid and low frequencies. The series are in phase in areas of high coherence.

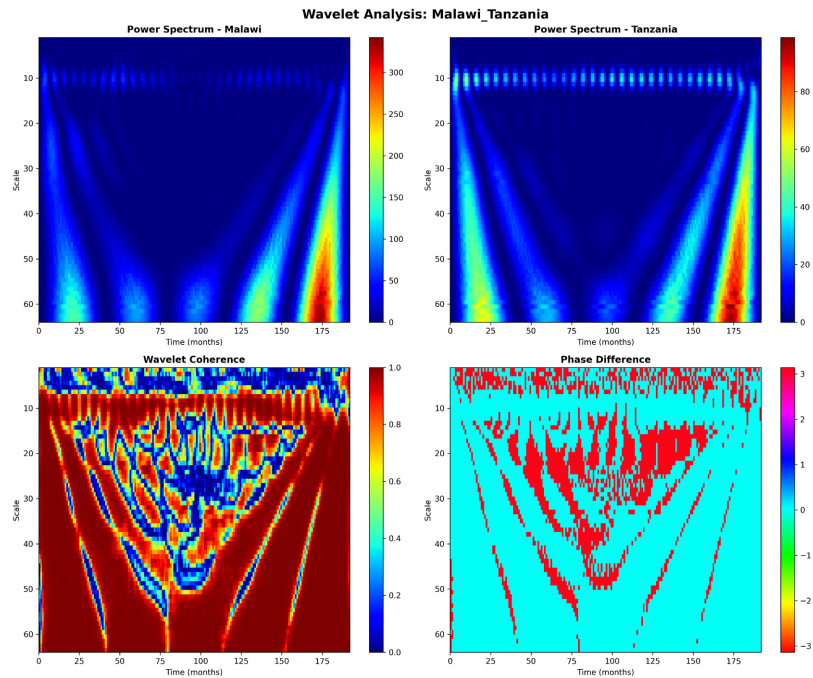


Figure 17. Wavelet analysis: Malawi-Tanzania.

Malawi-Zambia (**Figure 18**): Strong and persistent coherence in the mid and low frequencies. The series are in phase, suggesting strong synchronization.

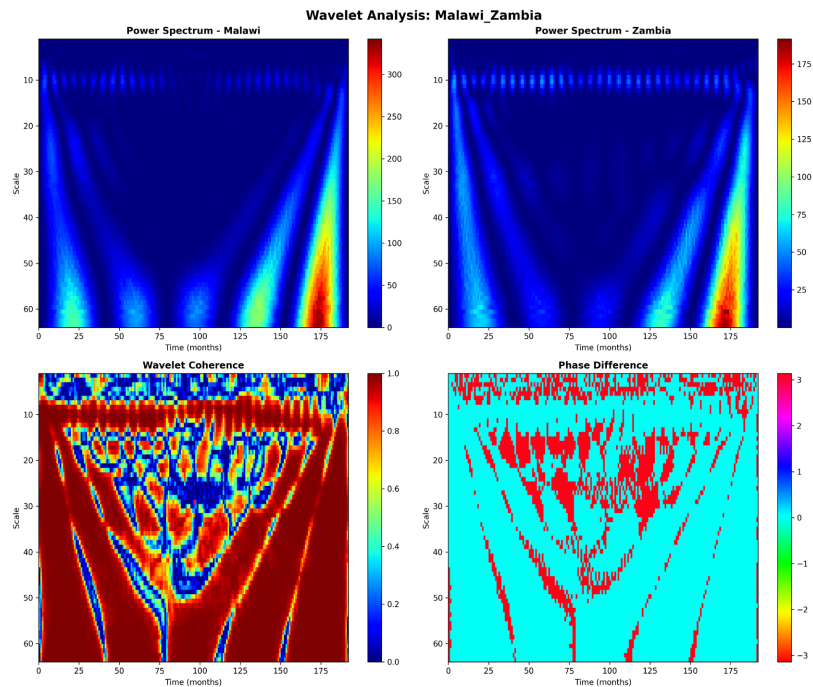


Figure 18. Wavelet analysis: Malawi-Zambia.

4.5. Pairs Implying South Africa (Outside Botswana, Lesotho, Madagascar and Malawi)

South Africa-Tanzania (**Figure 19**): Moderate coherence at mid and low frequencies. The series are in phase in areas of high coherence.

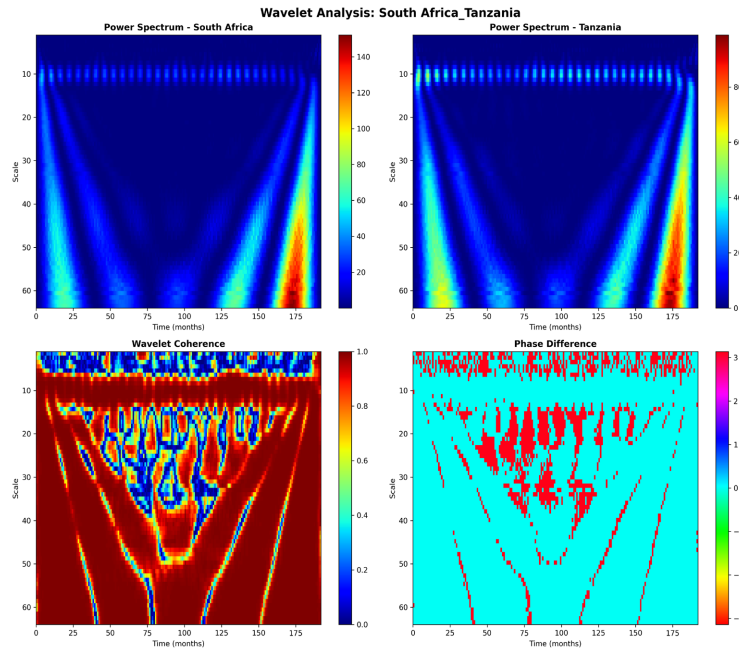


Figure 19. Wavelet analysis South Africa-Tanzania.

South Africa-Zambia (**Figure 20**): Strong coherence at mid and low frequencies. The series is in phase, indicating significant synchronization.

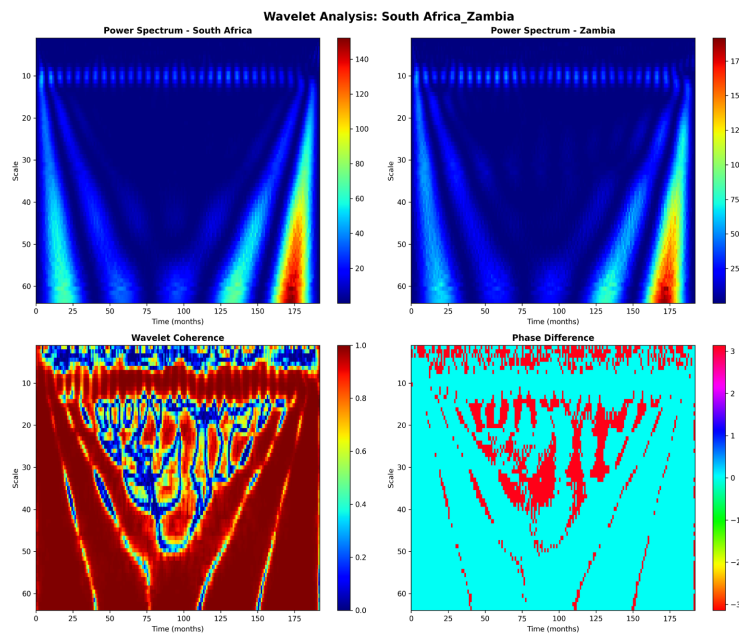


Figure 20. Wavelet analysis: South Africa-Zambia.

4.6. Pairs Implying Tanzania (Outside Botswana, Lesotho, Madagascar, Malawi and South Africa)

Tanzania-Zambia (**Figure 21**): Moderate to strong coherence at mid and low frequencies. The series are in phase in areas of high coherence.

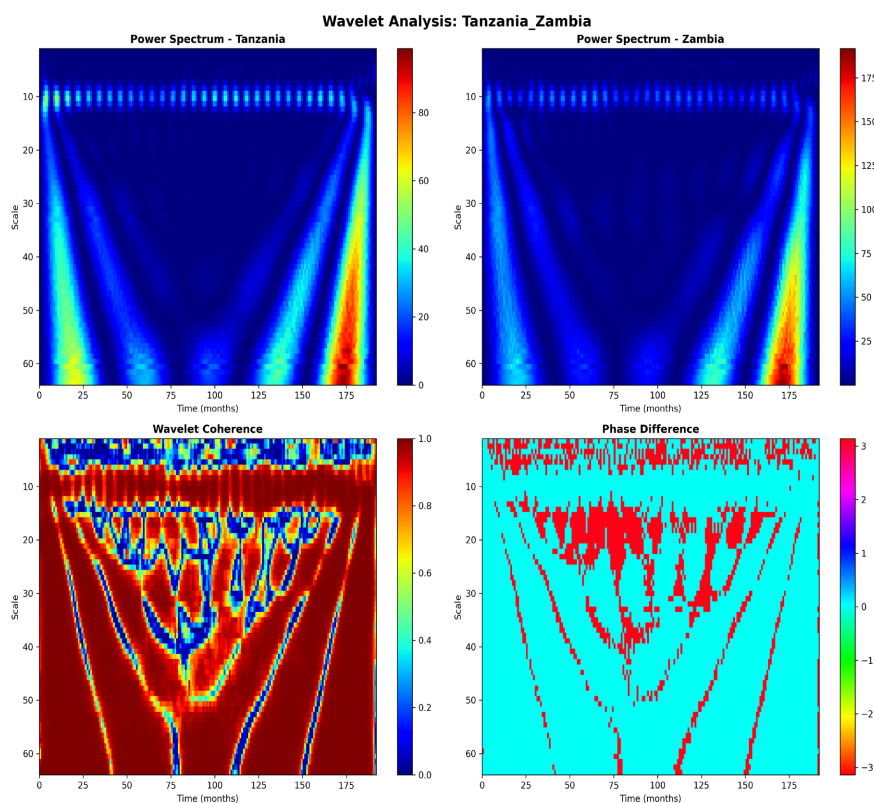


Figure 21. Wavelet analysis: Tanzania-Zambia.

5. Discussion

Wavelet analysis of inflation co-movements within SADC reveals heterogeneous integration patterns, which can be grouped into three main categories. This approach, which allows for the study of relationships between time series at different frequencies and over time (Tiwari et al., 2021a), is increasingly used in the economic literature to analyze the synchronization of business cycles and inflation (Fankem, 2023). Our results confirm this heterogeneity, in line with existing work on macroeconomic convergence in Africa (Tiwari et al., 2021b).

Strong Integration Core (South Africa and its immediate neighbors): The pairs involving South Africa, Botswana, and Lesotho exhibit the strongest and most persistent coherence across all frequencies, particularly in the medium and long term. This maximum synchronization reflects deep economic integration, close trade ties, and, in the case of Lesotho, monetary dependence (via the Rand Monetary Union or similar agreements). Inflationary shocks in this core are transmitted rapidly and synchronously, which is consistent with studies highlighting South Africa's dominant influence over its immediate neighbors (Campbell & Shiller,

1987).

Moderate Integration Group (Malawi and Zambia): Pairs involving Malawi and Zambia (among themselves and with the strong core) show significant coherence, primarily at mid- and low frequencies. This suggests that inflation cycle synchronization occurs over the long term, indicating the influence of common fundamentals and regional shocks, but that short-term shocks remain more country-specific. The strong coherence between Malawi and Zambia also suggests the existence of an integration subgroup within SADC, reinforcing the idea that regional convergence occurs in blocs rather than uniformly (Mkhombo & Phiri, 2023).

Disconnected Countries (Madagascar and Tanzania): Pairs involving Madagascar and Tanzania (among themselves and with most other countries) exhibit the weakest and most erratic coherence. This indicates that their inflation dynamics are largely independent of the rest of the sample. Inflationary shocks in these countries are primarily domestic in origin, or they are affected by different international shocks. Geographic distance and less integrated economic structures likely explain this disconnect, a finding often observed in co-movement analyses among African countries (Fankem, 2023).

6. Final Remarks

This study explored the co-movement dynamics of inflation rates among SADC countries using continuous wavelet analysis. The results highlight significant heterogeneity in the degree of inflationary synchronization, allowing the countries to be classified into three distinct groups.

First, a core of strong integration—centered on South Africa and including Botswana and Lesotho—exhibits high and persistent coherence across the entire time and frequency spectrum. This synchronization reflects deep economic integration, close trade ties, and, in the case of Lesotho, currency dependence. Inflationary shocks in this core are transmitted rapidly and synchronously.

Second, a group of moderate integration, comprising Malawi and Zambia, displays significant coherence primarily in the medium and long term. This suggests that their synchronization with the regional core and among themselves occurs over the long term, likely driven by common economic fundamentals or regional shocks, while short-term dynamics remain more idiosyncratic.

Third, Madagascar and Tanzania appear largely disconnected from regional inflationary dynamics, with weak and sporadic coherence. Their inflationary trajectories seem primarily driven by domestic factors or sensitive to distinct international shocks, which can be explained by geographical distance and lower levels of structural integration.

The policy implications are twofold. For the core countries, coordinated monetary policies and enhanced monitoring of shock transmission channels are essential. For moderately integrated or disconnected countries, authorities should prioritize managing domestic inflationary drivers while considering measures to gradually strengthen their regional integration. Future research could further

identify the specific factors—such as trade, financial, or monetary policy channels—underpinning these co-movement patterns and extend the analysis to other developing regional economic blocs.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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