Financial Stress Dynamics in European Economies: A Wavelet Coherence Analysis

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Abstract

Keywords:

JEL Classification:

1.Introduction

Financial stress plays a critical role in shaping economic stability, influencing market behavior, and guiding policy decisions. The transmission of financial stress across economies can have profound effects on financial stability, making it essential to understand its dynamics, particularly during periods of crisis. Given the interconnected nature of financial markets, analyzing the co-movements of financial stress indices (FSI) across different economies can provide insights into systemic risks and contagion effects.

To examine financial stress dynamics, we employ wavelet coherence analysis, a technique that allows us to capture both time- and frequency-dependent relationships between financial stress indicators. Unlike traditional econometric models, which assume static or linear relationships, wavelet coherence is particularly well-suited for financial time-series data, as it enables:1) The identification of time-varying co-movements between financial stress indices,2) Detection of lead-lag relationships, allowing us to determine which country's financial stress reacts first to systemic shocks. ,3) Distinction between short-term and long-term dependencies, revealing different transmission mechanisms over time.

This methodology provides a more granular and dynamic perspective on financial transmission, highlighting periods of synchronization and decoupling between different financial markets. Our analysis reveals heterogeneous patterns of financial stress transmission, demonstrating that financial stress interdependencies vary significantly across countries, time periods, and financial sectors.

Literature Review

The link between financial stress, fiscal pressure, and macroeconomic instability has become a central theme in recent economic research. Many studies have developed stress indices and tested how shocks spread across sectors and countries. A variety of tools, from SVAR models to copulas and quantile-based analysis, have been used to uncover the nature and direction of these spillovers.

Both financial and fiscal stress have been shown to reduce output and inflation. However, their interaction is not always symmetric; fiscal stress may respond to financial shocks, but not always the other way around. These results were obtained using financial and fiscal stress indices for the G7 economies and a Structural VAR model (Magkonis & Tsopanakis, 2014).

Evidence from G5 economies confirmed strong two-way transmission between financial and fiscal stress, particularly after the 2008 financial crisis. This supports the argument for better coordination between fiscal and financial policy. The findings were based on spillover indices and causality analysis (Magkonis & Tsopanakis, 2016).

In the Euro area, larger economies like France and Italy were found to be more interconnected during positive market conditions, while smaller economies tended to cluster during distress periods. Spain, Italy, France, and Belgium emerged as central nodes in the stress network. These insights were derived using an R-vine copula model built on ARMA-GARCH processes (Zhang, Yan & Tsopanakis, 2018).

Italy and Spain were also identified as major transmitters of stress within the GIIPS group and Germany, especially through banking and equity markets. In contrast, Greece and Portugal had smaller roles in amplifying financial stress. These conclusions were drawn using sector-level stress indices and network analysis (Magkonis & Tsopanakis, 2020).

In emerging markets, financial stress from developed countries was found to increase exchange market pressure, particularly during high-volatility regimes. This effect was asymmetric and regime-dependent. The study applied a nonlinear VAR model and quantile regression to data from Brazil, China, Mexico, Russia, and South Korea (Ozcelebi, 2020).

Most Eurozone countries were found to respond primarily to their own financial shocks, though some regional clustering existed. Peripheral economies showed greater internal vulnerability, while Greece and Portugal had limited systemic impact. These findings came from country-specific financial stress indices and a VAR analysis (MacDonald, Sogiakas & Tsopanakis, 2015).

In Lebanon, a new financial stress index was introduced to help monitor systemic risk in a highly dollarized and fragile financial system. The index covered banking, equity, and exchange rate markets. It was constructed as a composite, real-time monitoring tool (Ishrakieh, Dagher & El Hariri, 2020).

In the case of Turkey, financial stress was shown to reduce output and increase government debt, while debt itself heightened financial stress. Conversely, economic growth reduced both. These results came from a Bayesian VAR model using a custom financial stress index over a long historical period (Kasal, 2023).

In the United States, financial stress components were found to behave differently depending on market conditions. During normal times, credit and U.S. sectors transmitted shocks. But during crises, such as COVID-19 or the SVB collapse, U.S.

financial sectors became net receivers. The study used a quantile VAR model to examine spillovers under different volatility regimes (Hoque et al., 2024).

Finally, a global financial stress index showed strong correlation with the VIX and revealed that gold and the U.S. dollar were its most influential components. The index remained robust under different weighting methods. It was constructed using principal component analysis and regression techniques applied to oil, gold, the USD index, NASDAQ, and the EUR/USD exchange rate (Reisizadeh, Fallah Shams & Zomoredian, 2025).

2.Methodology

Following Torrence and Webster (1998) we define the wavelet coherence of two time series, namely x_t and y_t, with $W_x(\tau, s)$ and $W_y(\tau,s)$ wavelet transforms as the absolute value squared of the smoothed cross-wavelet spectrum, normalized by the smoothed wavelet power spectra:

$$R^2(\tau,s) = \frac{\left|S(s^{-1}W_{xy}(\tau,s)\right|^2}{S(s^{-1}|W_x(\tau,s)|^2)\cdot S\left(s^{-1}\left|W_y(\tau,s)\right|^2\right)}$$

where S(.) is the smoothing operator and s is the wavelet scale.

The white contour designates the 5% significance level estimated from the Monte Carlo simulations using the phase randomized surrogate series. The cone of influence, where edge effects might distort the picture, is shown as a lighter shade. Regions of differing coherency are represented using a heat map, which ranges from blue (low coherency) to red (high coherency). Y-axis measures frequencies or scale and X-axis shows the time-period studied (2001-2013). The phase differences between the two series are indicated by arrows. Arrows pointing to the right mean that the variables are in-phase (move in the same direction, having cyclical effects on each other). If the arrows point to the right and up, then the first index is leading (the first index causes the second one). If the arrows point down, the first index is lagging. Arrows pointing to the left mean

that the variables are out-of-phase (have anti-cyclical effects on each other). If the arrows point to the left and up, the first index is leading, and if they point to the left and down, the first index is lagging.

3. Data and Preliminary analysis

This study investigates the time and frequency dynamics of financial stress across eleven European countries—Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, and Spain. By examining both aggregate and disaggregated financial stress indices, we assess how stress produces across different financial segments, including bonds, stocks, money markets, and banking. This disaggregated perspective offers a nuanced understanding of the sectoral interdependencies that drive financial stress transmission, allowing for a more comprehensive assessment of systemic risk.

The selected countries represent a diverse cross-section of the Eurozone, encompassing both core and peripheral economies with varying degrees of financial stability and market structures. Core economies (e.g., Germany, France, the Netherlands, Austria, Belgium, Finland) exhibit stronger financial resilience and more stable banking systems, making them key reference points for financial contagion analysis. Peripheral economies (e.g., Greece, Ireland, Italy, Portugal, and Spain) faced significant challenges during the European Sovereign Debt Crisis (ESDC), making them crucial for understanding financial vulnerabilities and systemic risks.

The inclusion of these countries allows for a comparative analysis of financial stress transmission across economies with different fiscal policies, regulatory environments, and financial market structures. The interplay between core and peripheral economies provides critical insights into how financial instability spreads within the Eurozone and the potential implications for economic integration and policy coordination.

The time period 2001–2013 is selected because it captures two of the most significant financial crises in recent history, both of which had profound effects on the European economy: The Global Financial Crisis (GFC) of 2007–2009 – This period was marked

by the collapse of major financial institutions, liquidity constraints, and extreme market volatility. The crisis originated in the United States but had severe repercussions across Europe, affecting banking stability and financial market performance. The European Sovereign Debt Crisis (ESDC) of 2010–2012 – This crisis emerged from unsustainable government debt levels, particularly in Southern European countries. It led to severe market disruptions, widening bond yield spreads, and instability in the banking sector. By covering both crises, our analysis provides a comprehensive view of financial stress evolution, capturing its dynamics before, during, and after these shocks. This approach enables us to identify long-term and short-term financial interdependencies, shedding light on the varying intensity and nature of financial stress over time.

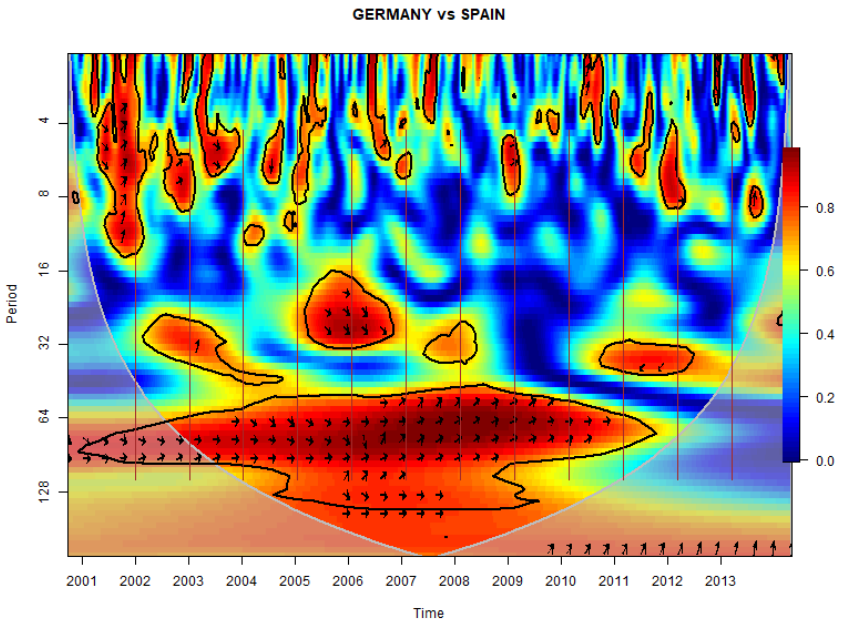
4. Empirical Results

In this section we analyze the empirical results from Wavelet coherence analysis aim to address the research questions according to volatility movement in time and frequency analysis. We analyze the relationship between Germany and other countries using the German as benchmark economy.

Να σχολιάσω τα αποτελέσματα

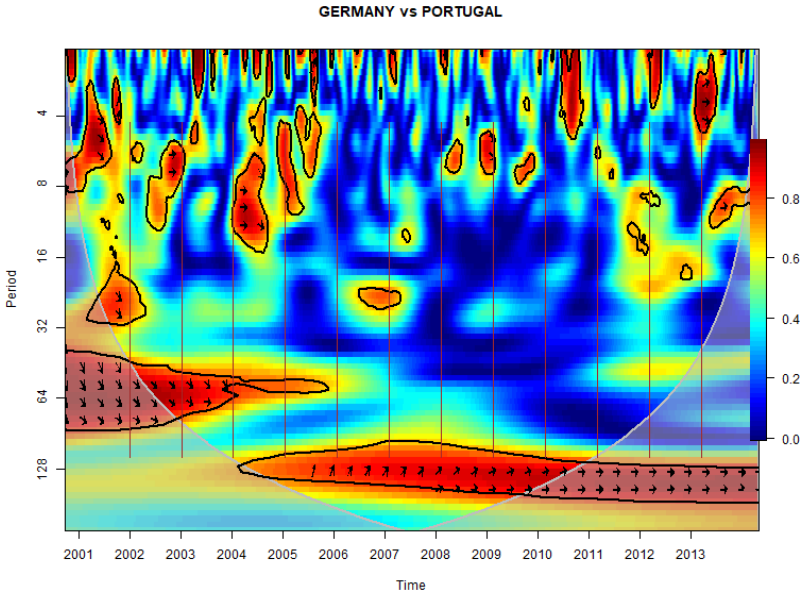
4.1 Aggregated Stress Index

Figure 1



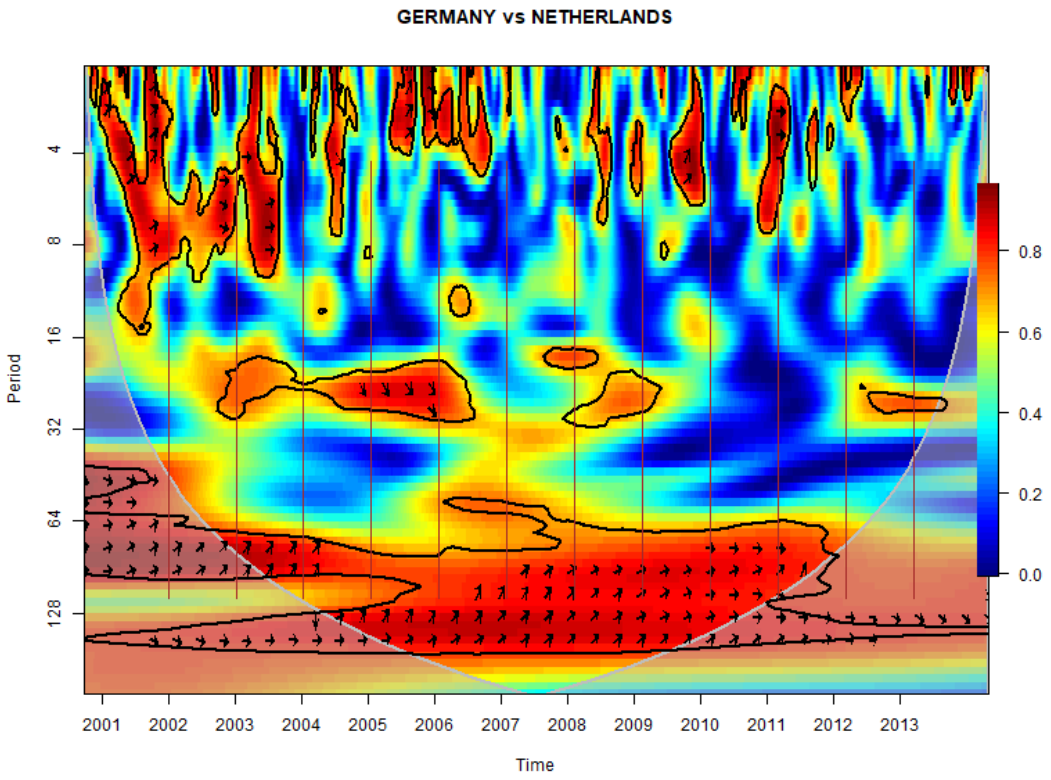
The wavelet coherence analysis between Germany and Spain indicates intermittent short-term co-movements, notably more intense around 2002. In the long term, a sustained and significant co-movement is observed from 2003 to 2011, with phase arrows predominantly pointing right, suggesting a strong in-phase relationship.

Figure 2



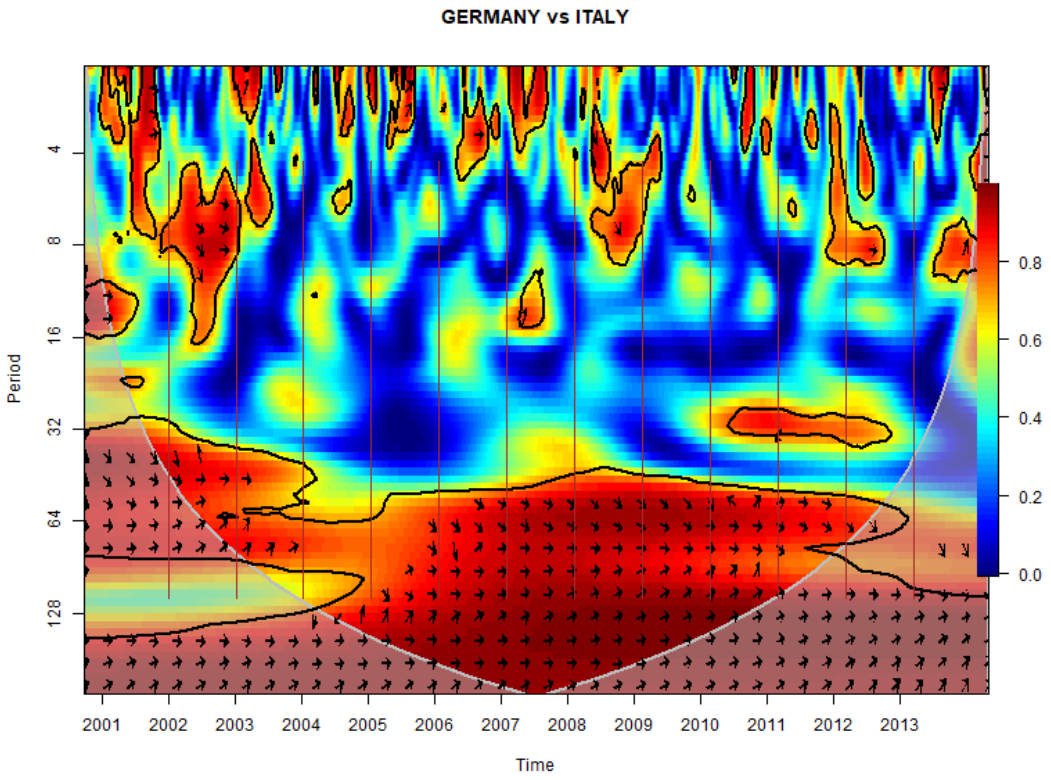
The wavelet coherence analysis reveals intermittent short-term co-movements around 2002–2003. In the long term, a sustained and significant co-movement is observed from 2005 to 2012, with arrows predominantly pointing to the right, indicating an in-phase relationship between the two variables.

Figure 3



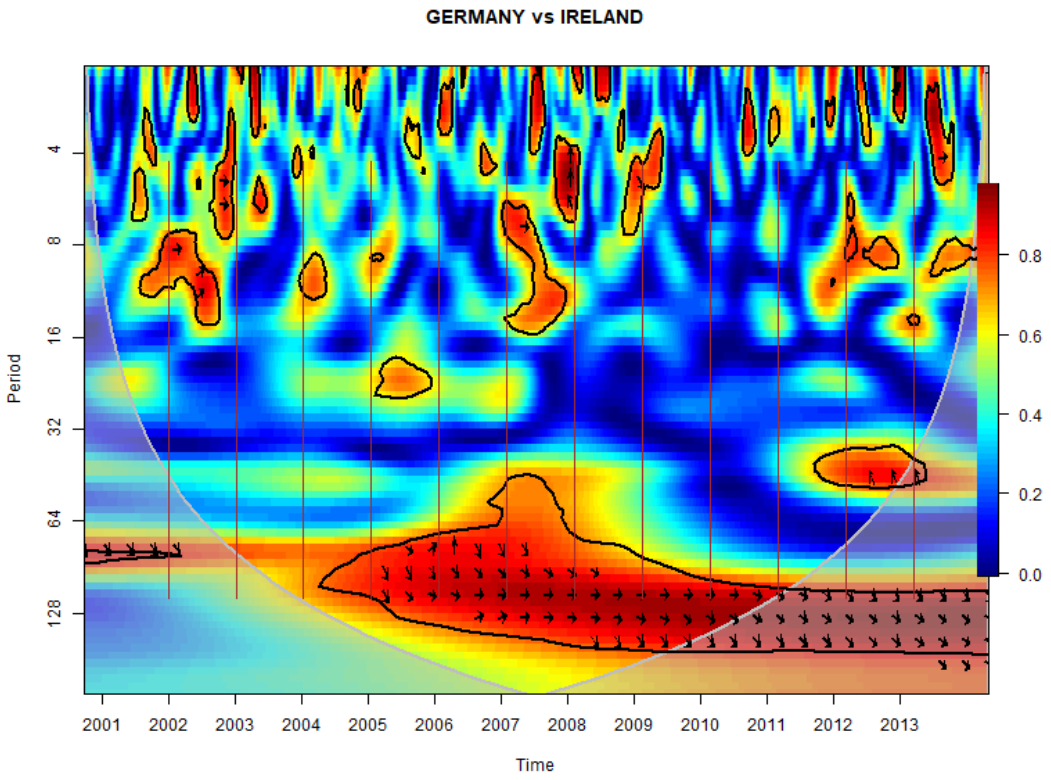
The wavelet coherence analysis shows intermittent short-term co-movements, particularly pronounced in the early 2000s. A strong and persistent long-term co-movement is evident from 2003 to 2012, with phase arrows consistently pointing to the right, indicating a robust in-phase relationship between the two variables.

Figure 4



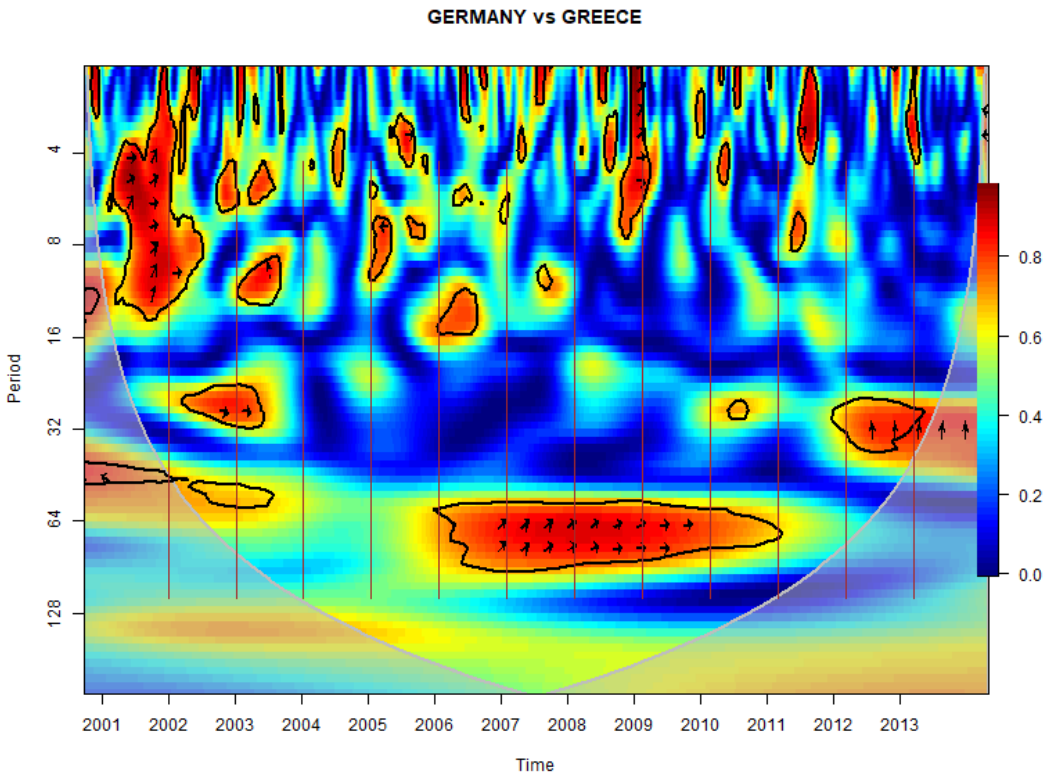
The wavelet coherence analysis indicates limited short-term co-movement, with some activity around 2002–2004. In the long-term, a strong and sustained co-movement emerges from 2005 to 2012, with arrows predominantly pointing to the right, reflecting a clear in-phase relationship between the two variables over this period.

Figure 5



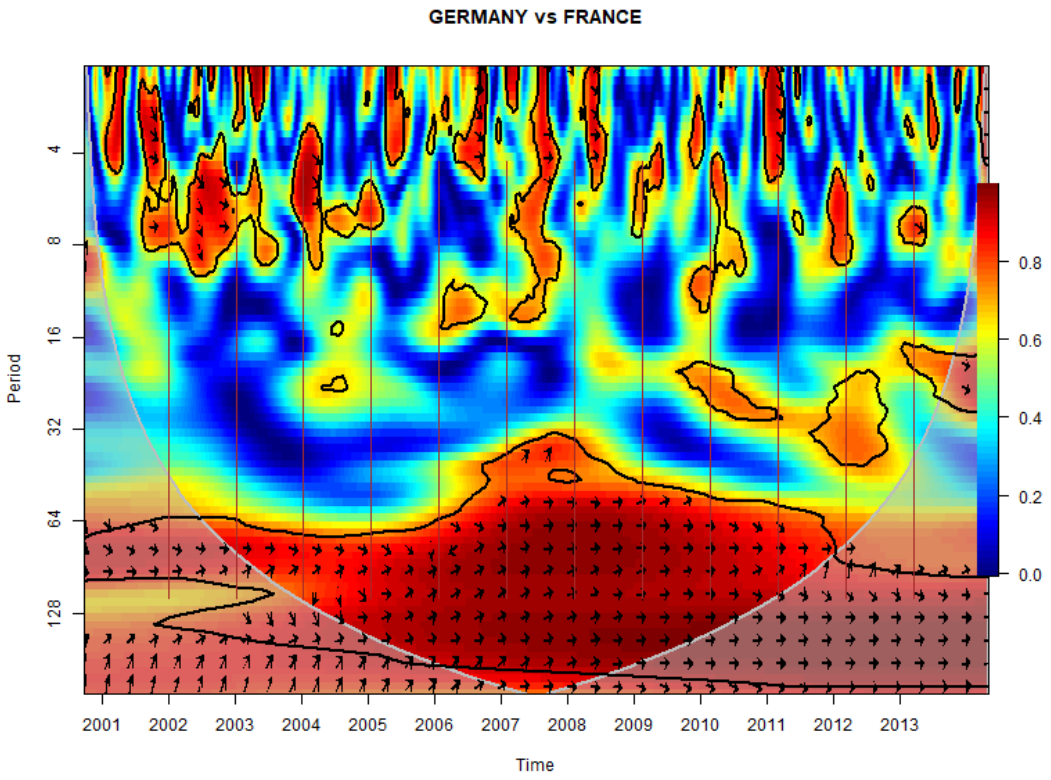
The wavelet coherence analysis shows minimal short-term co-movement, with isolated episodes of significance. A notable long-term co-movement is present from approximately 2005 to 2011, where arrows predominantly point to the right, indicating an in-phase relationship between the two variables.

Figure 6



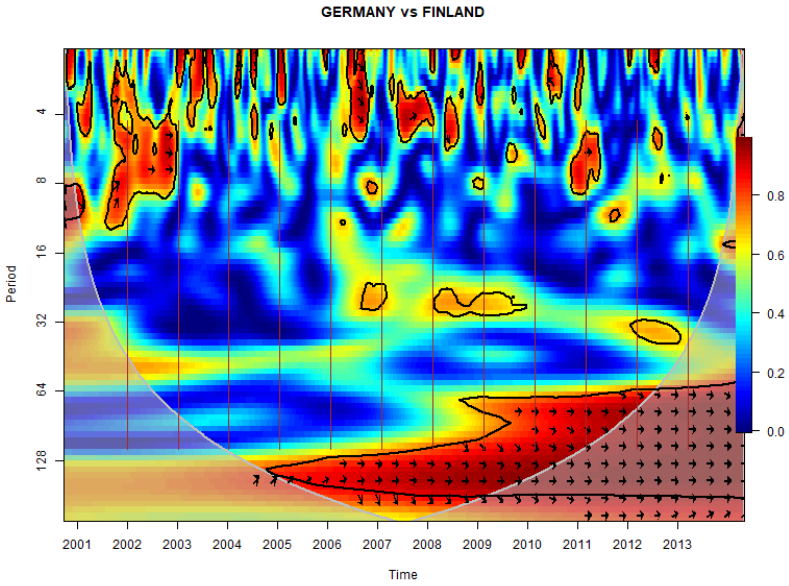
The wavelet coherence analysis reveals isolated short-term co-movements, particularly around 2002 and 2013. A moderate long-term co-movement is observed between 2006 and 2009, with arrows generally pointing to the right, indicating periods of in-phase behavior between the two variables during this interval.

Figure 7



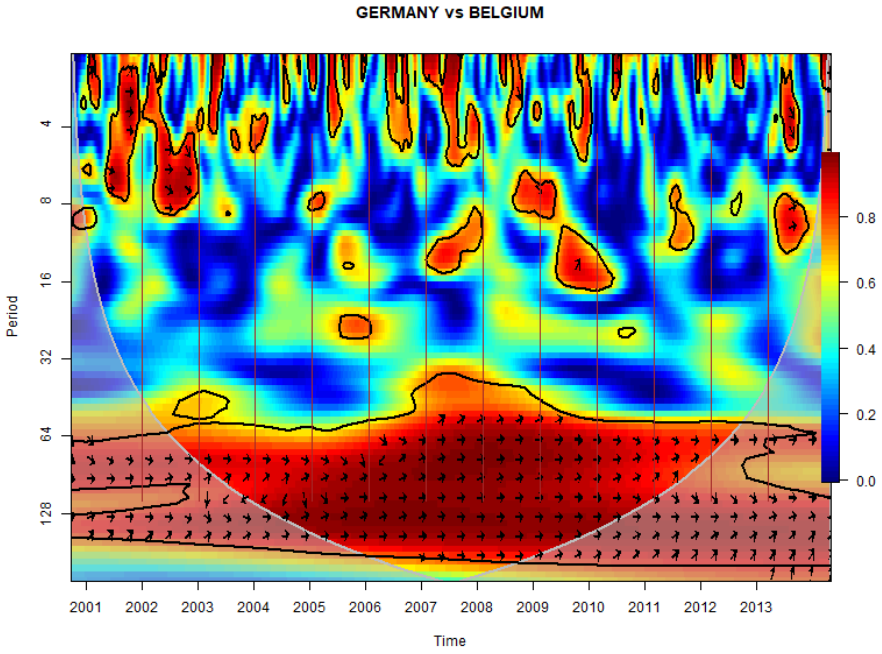
The wavelet coherence analysis reveals limited short-term co-movements in the early 2000s. However, a pronounced and persistent long-term co-movement is evident from approximately 2003 to 2011, with arrows predominantly oriented to the right, indicating a strong in-phase relationship between the two variables throughout this period.

Figure 8



The wavelet coherence analysis indicates minimal short-term co-movement over the sample period. However, a strong and persistent long-term co-movement emerges from approximately 2007 onward, with arrows consistently pointing to the right, suggesting a clear in-phase relationship between the two variables during this period.

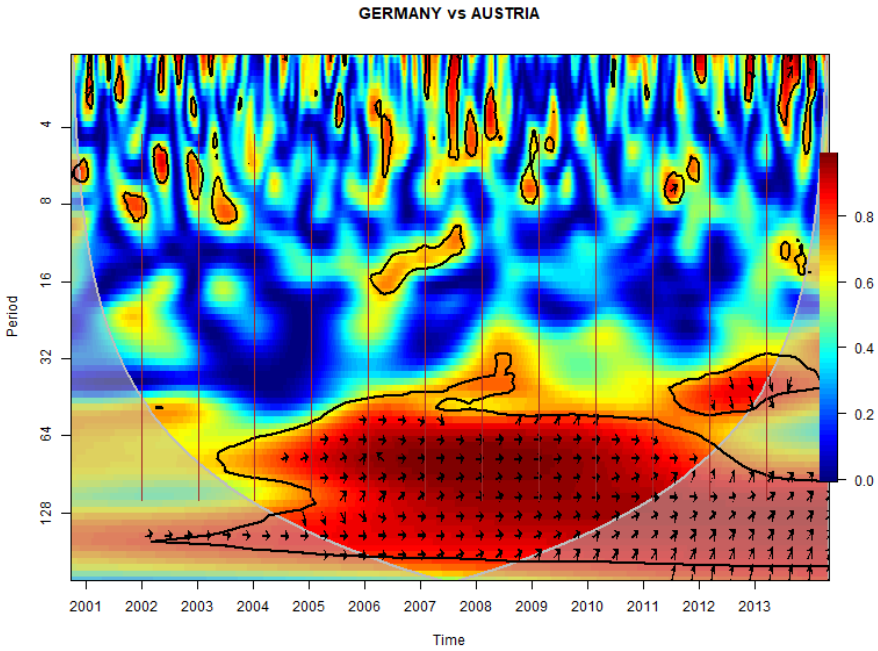
Figure 9



The wavelet coherence analysis reveals occasional short-term co-movements, particularly in the early 2000s. A strong and persistent long-term co-movement is observed from

approximately 2003 to 2012, with arrows consistently pointing to the right, indicating a pronounced in-phase relationship between the two variables during this period.

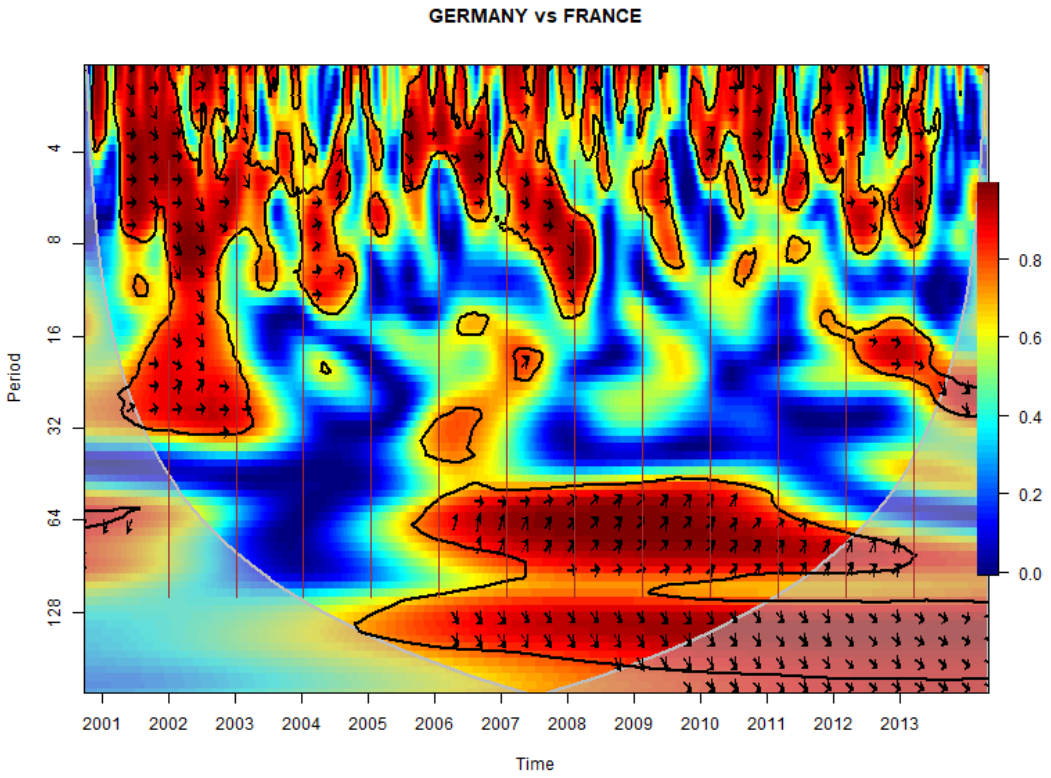
Figure 10



The wavelet coherence analysis indicates isolated short-term co-movements in the early part of the sample. A strong and sustained long-term co-movement emerges from approximately 2005 to 2012, with arrows predominantly pointing to the right, suggesting a consistent in-phase relationship between the two variables over this period.

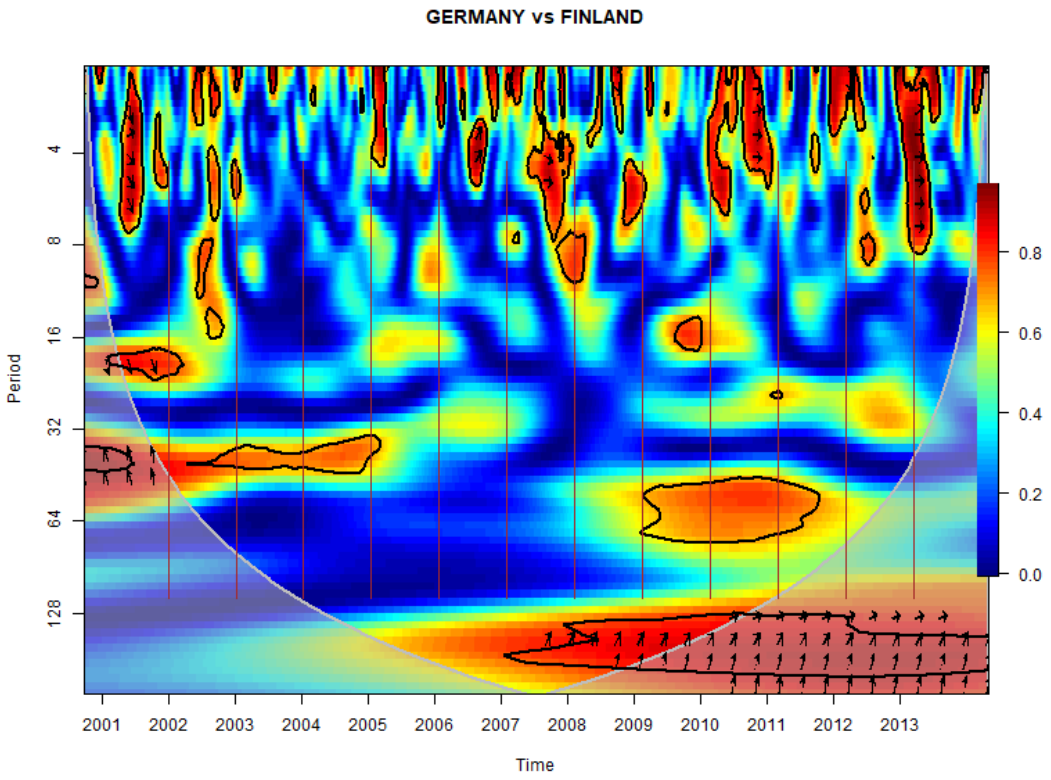
4.2 Banking Stress Index

Figure 11



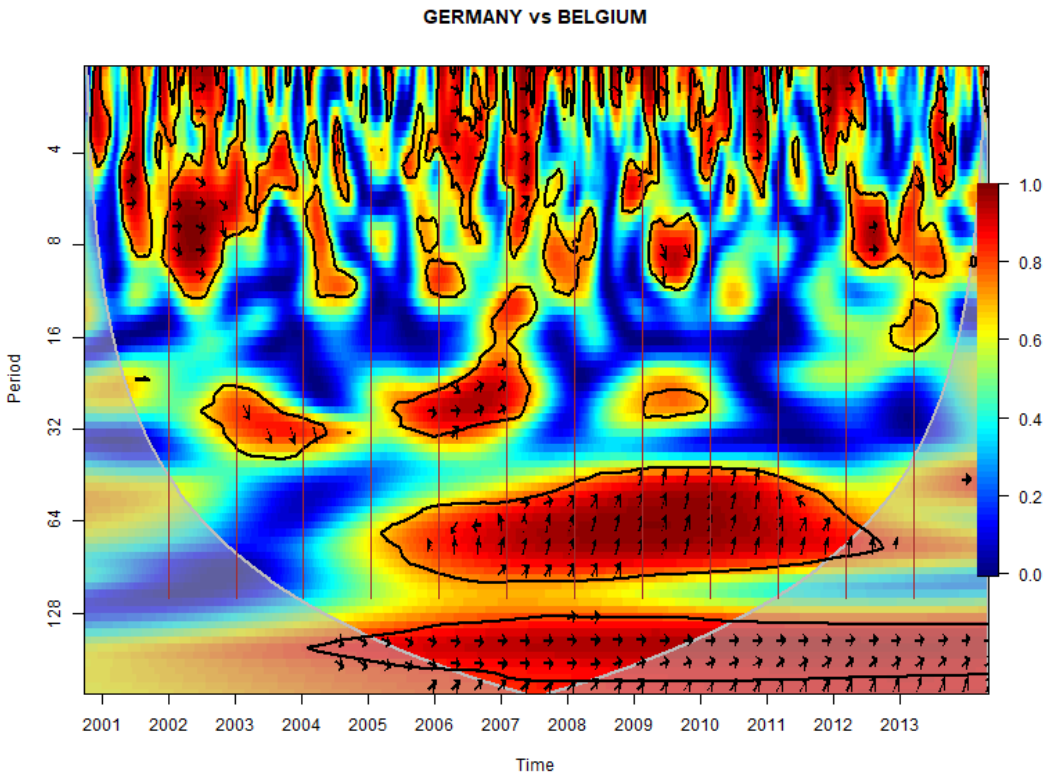
The wavelet coherence analysis demonstrates frequent short-term co-movements throughout the sample period, particularly strong in the early 2000s. In the long term, a pronounced and sustained co-movement is observed from approximately 2006 to 2012. Arrows during this interval predominantly point to the right, indicating a consistent in-phase relationship between the two variables.

Figure 12



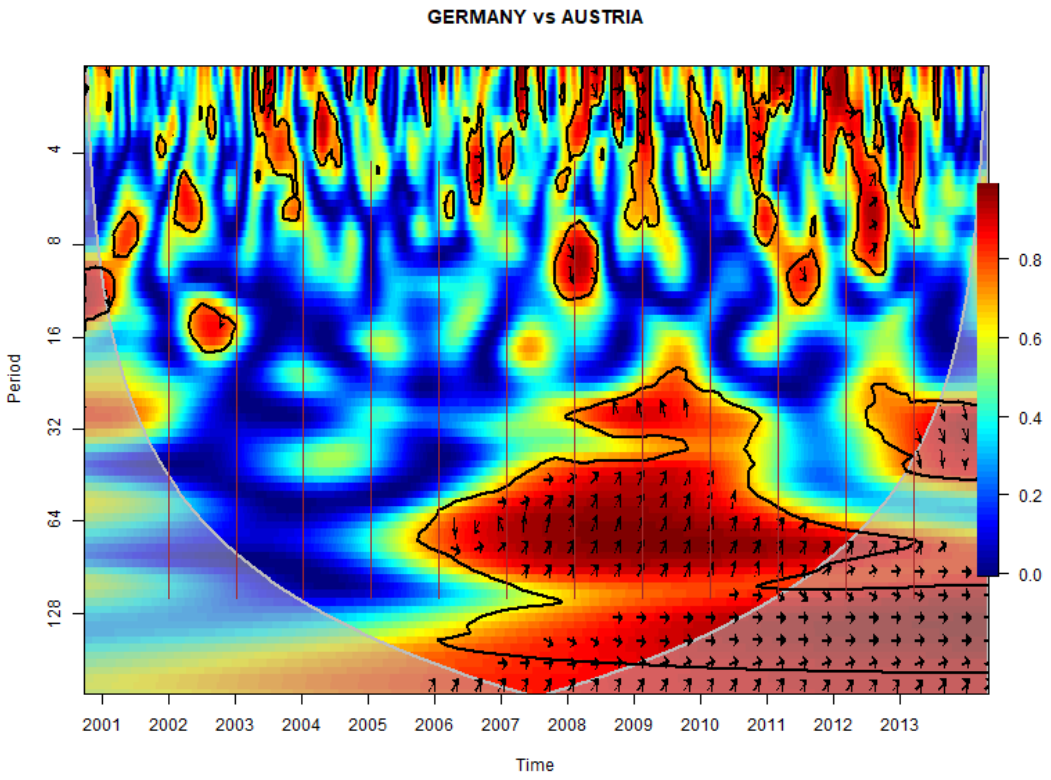
The wavelet coherence analysis reveals limited short-term co-movement, with a few scattered episodes of significance. A moderate long-term co-movement emerges around 2008 and becomes more pronounced from 2011 to 2013. During this later period, arrows predominantly point to the right, indicating a developing in-phase relationship between the two variables.

Figure 13



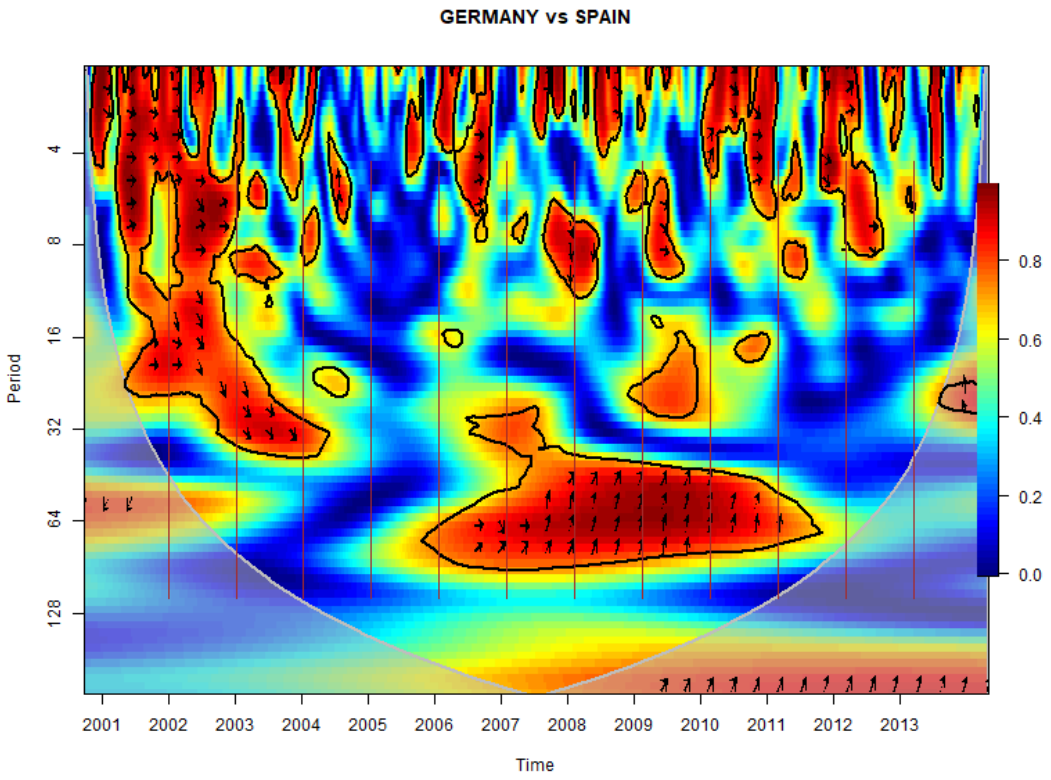
The wavelet coherence analysis reveals intermittent short-term co-movements, particularly between 2002 and 2004. A strong and persistent long-term co-movement is evident from approximately 2006 to 2012, with arrows predominantly oriented to the right, indicating a stable in-phase relationship between the two variables over this period.

Figure 14



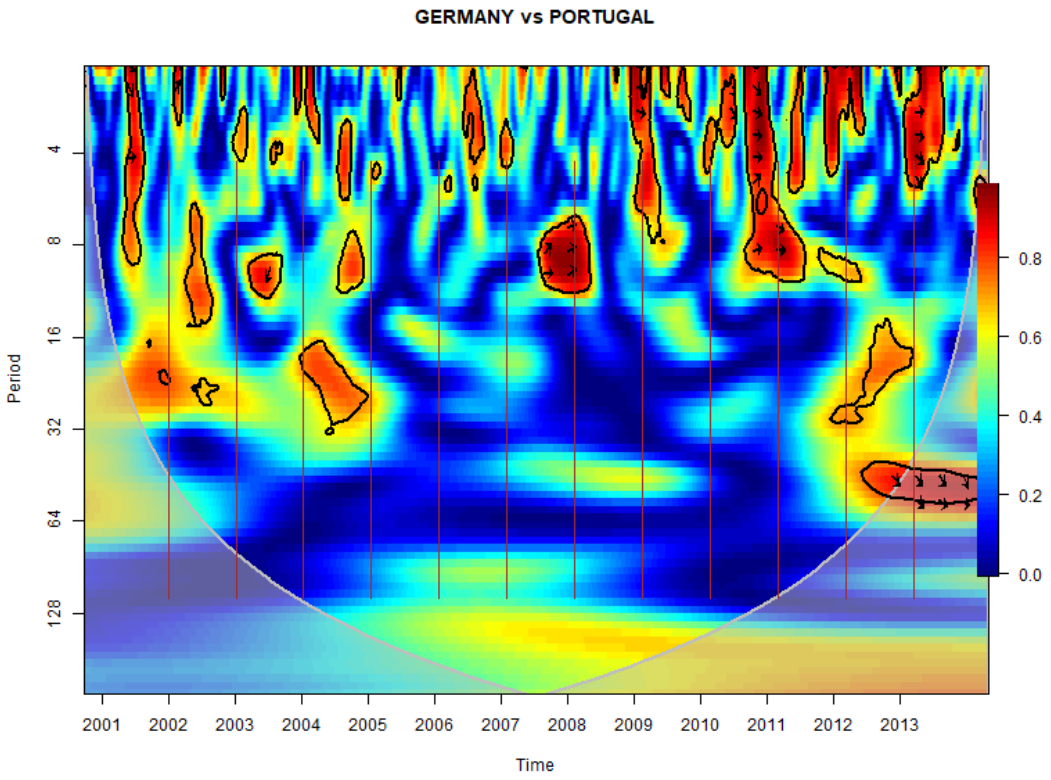
The wavelet coherence analysis indicates negligible short-term co-movement in the early years of the sample. From approximately 2007 to 2013, a strong and persistent long-term co-movement emerges, with arrows predominantly pointing to the right, reflecting a stable in-phase relationship between the two variables during this period.

Figure 15



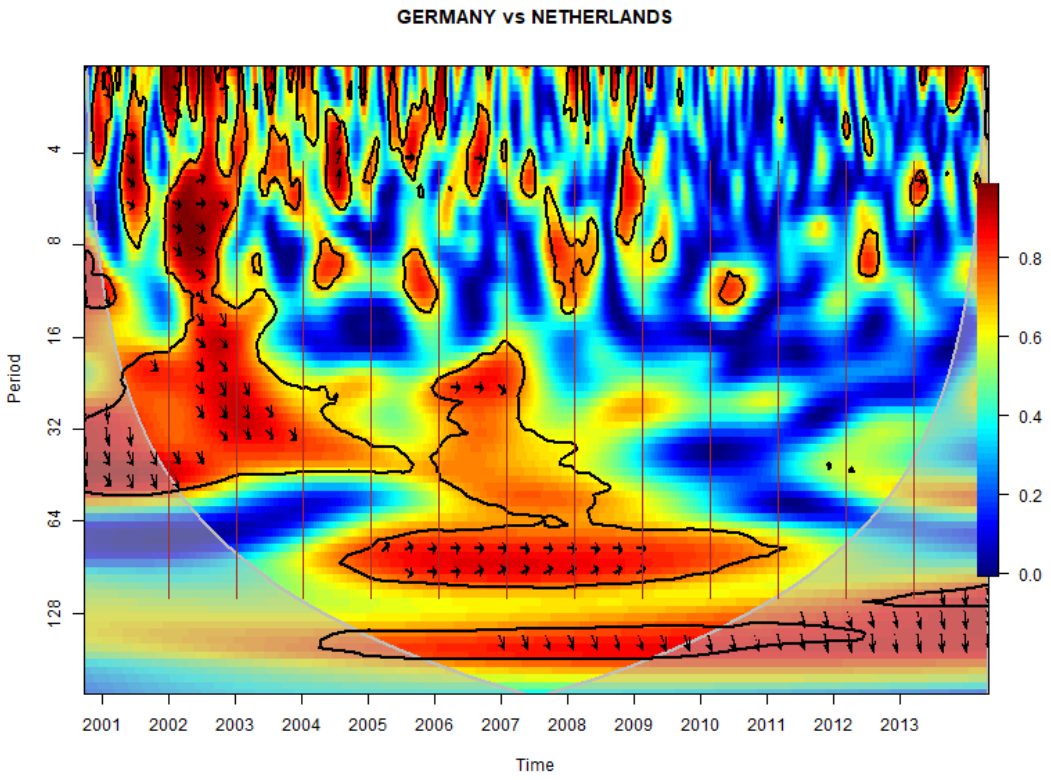
The wavelet coherence analysis reveals intermittent short-term co-movements, particularly around 2002–2004. A clear and moderately strong long-term co-movement is observed from approximately 2006 to 2011, with arrows predominantly pointing to the right, indicating a stable in-phase relationship between the two variables during this period.

Figure 16



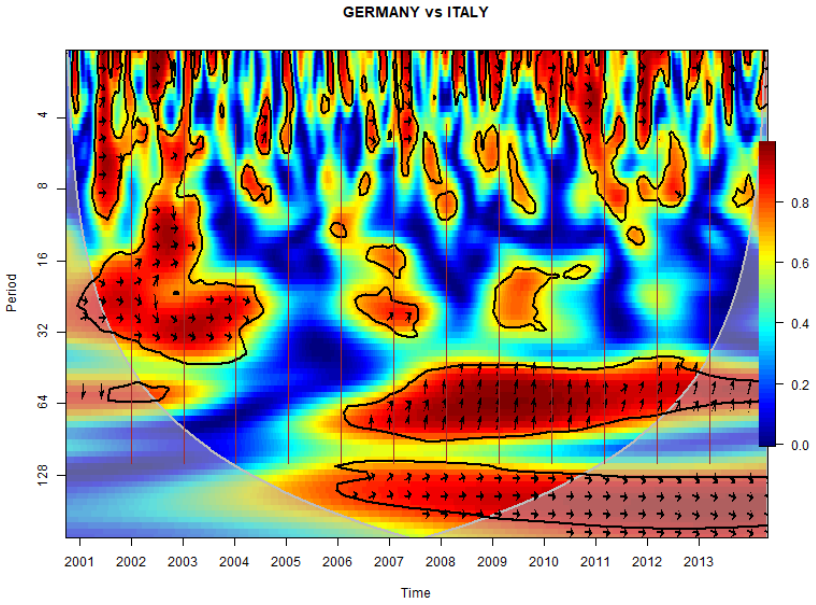
The wavelet coherence analysis reveals limited and sporadic short-term co-movements throughout the sample period. A weak but emerging long-term co-movement appears around 2012–2013, with arrows pointing to the right, indicating a developing in-phase relationship between the two variables in the latter part of the period.

Figure 17



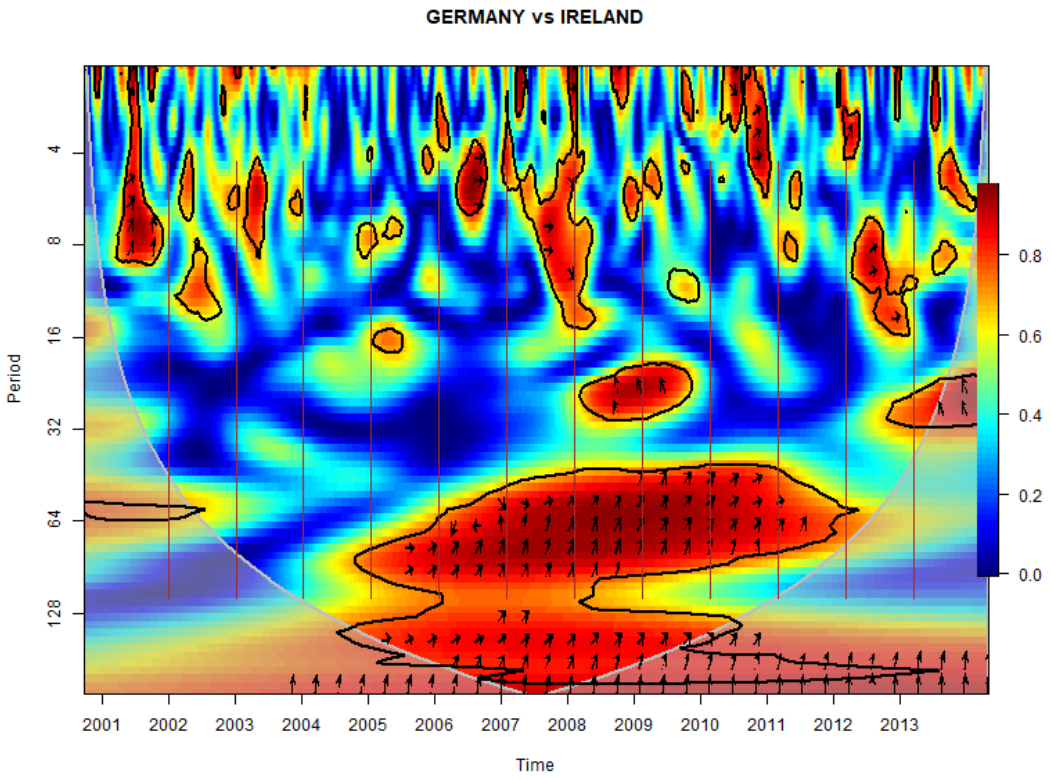
The wavelet coherence analysis indicates frequent short-term co-movements, particularly evident between 2001 and 2005. A strong and persistent long-term co-movement emerges from around 2004 to 2011, with arrows predominantly pointing to the right, suggesting a stable in-phase relationship between the two variables during this period.

Figure 18



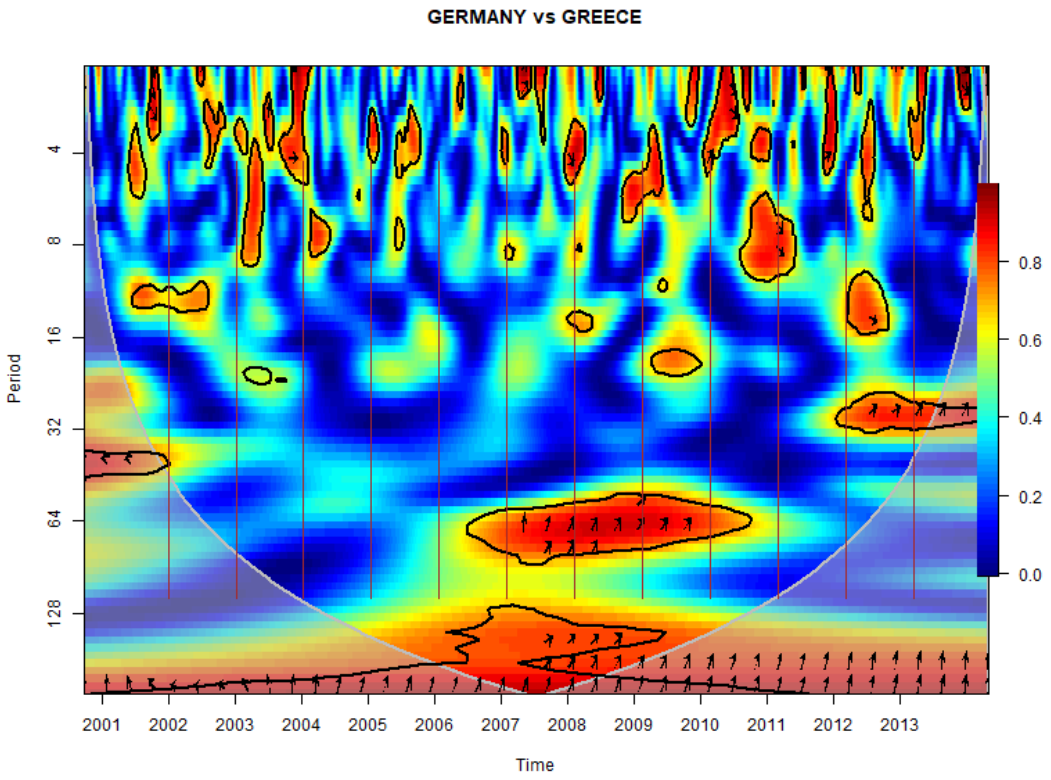
The wavelet coherence analysis shows notable short-term co-movements between 2001 and 2004. In the long term, a strong and persistent co-movement is observed from around 2006 to 2012, with arrows predominantly pointing to the right, indicating a stable in-phase relationship between the two variables during this period.

Figure 19



The wavelet coherence analysis reveals limited short-term co-movement, with a few isolated episodes. A strong and persistent long-term co-movement is observed from approximately 2006 to 2012, with arrows predominantly pointing to the right, indicating a stable in-phase relationship between the two variables throughout this period.

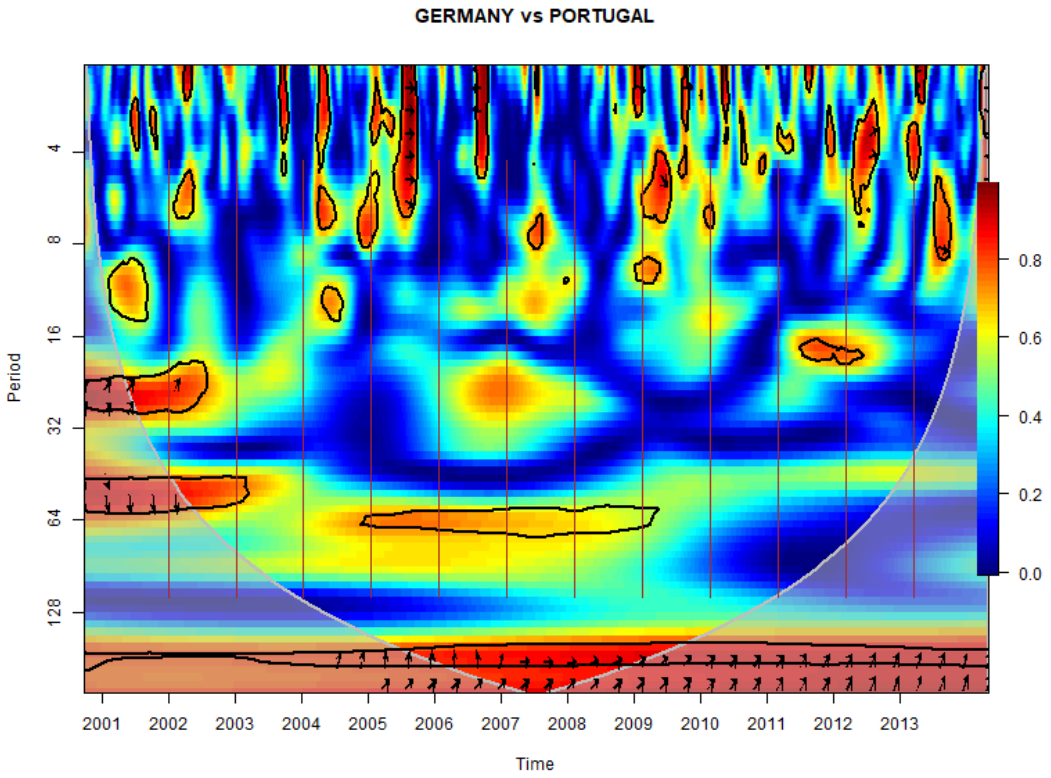
Figure 20



The wavelet coherence analysis indicates weak and infrequent short-term co-movements. A moderate long-term co-movement is observed from approximately 2006 to 2010, with arrows generally pointing to the right, suggesting an in-phase relationship between the two variables during this period.

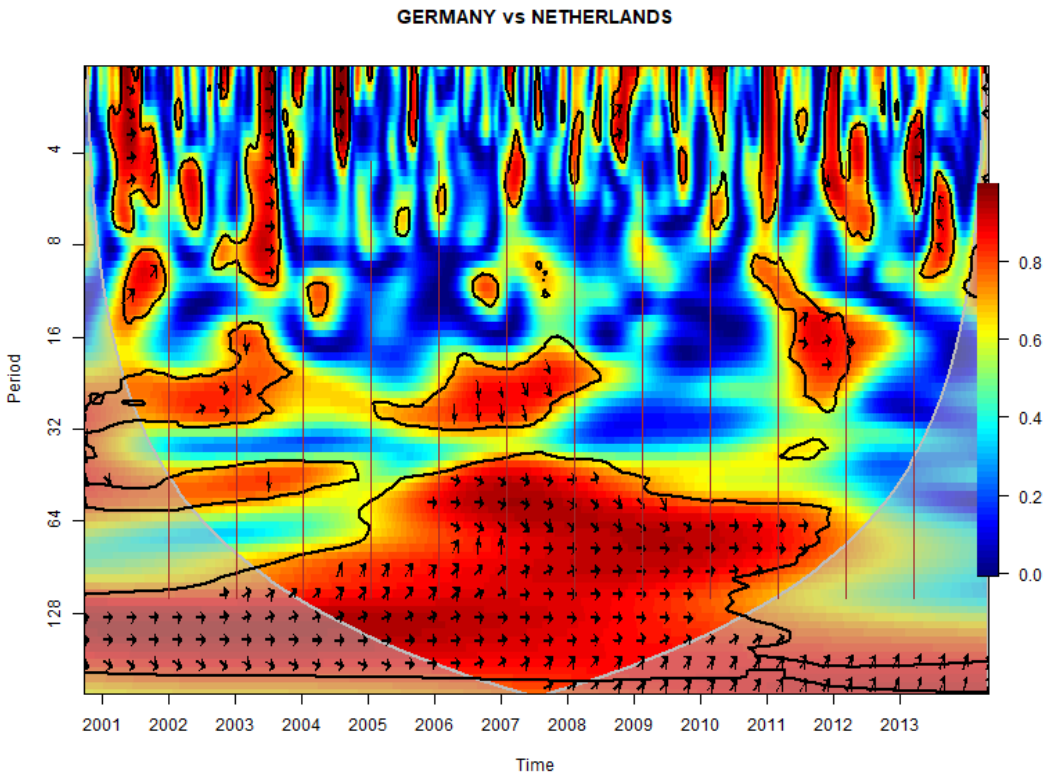
4.3 Bond Stress Index

Figure 21



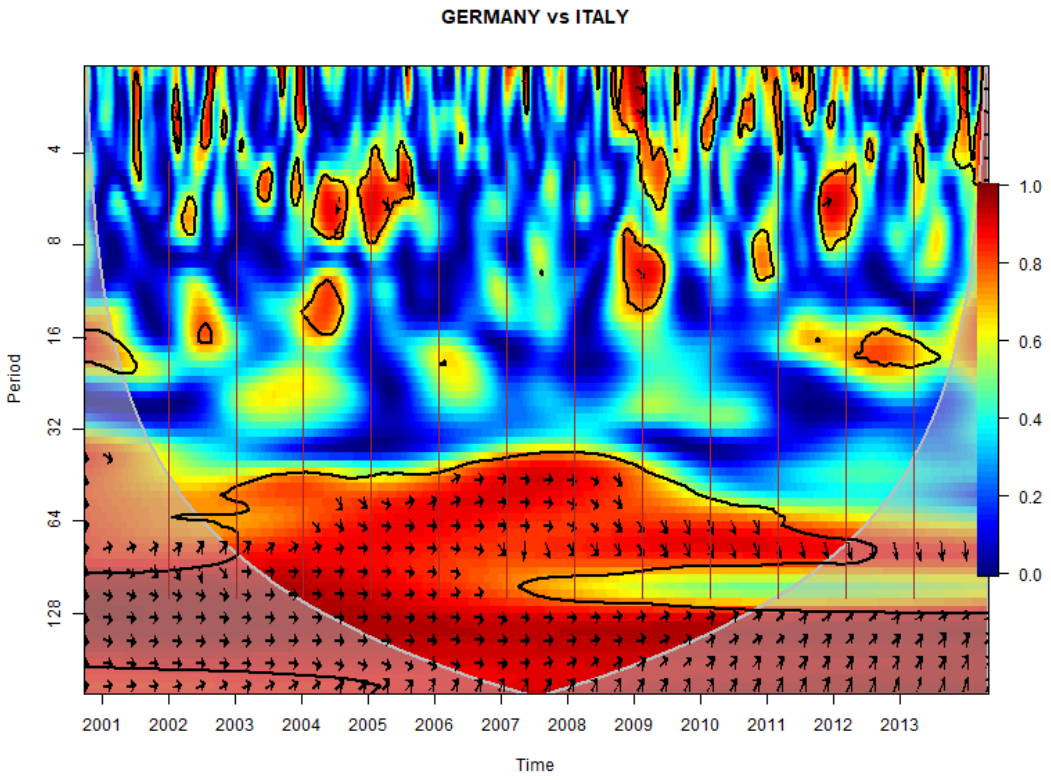
The wavelet coherence analysis reveals sparse short-term co-movements, primarily between 2001 and 2003. A clearer long-term co-movement appears from around 2006 to 2011, particularly in long term period. During this period, arrows predominantly point to the right, indicating a consistent in-phase relationship between the two variables.

Figure 22



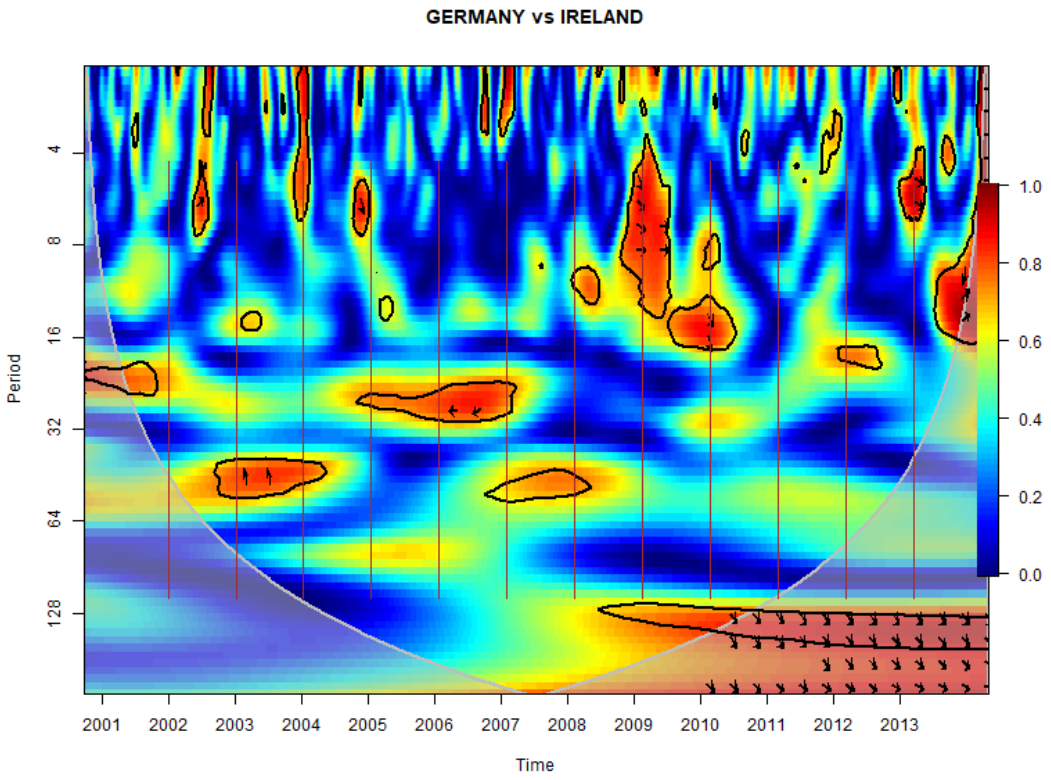
The wavelet coherence analysis reveals frequent short-term co-movements throughout the early part of the sample, particularly between 2001 and 2005. A strong and persistent long-term co-movement is evident from approximately 2006 to 2011, with arrows predominantly pointing to the right, indicating a consistent in-phase relationship between the two variables over this period.

Figure 23



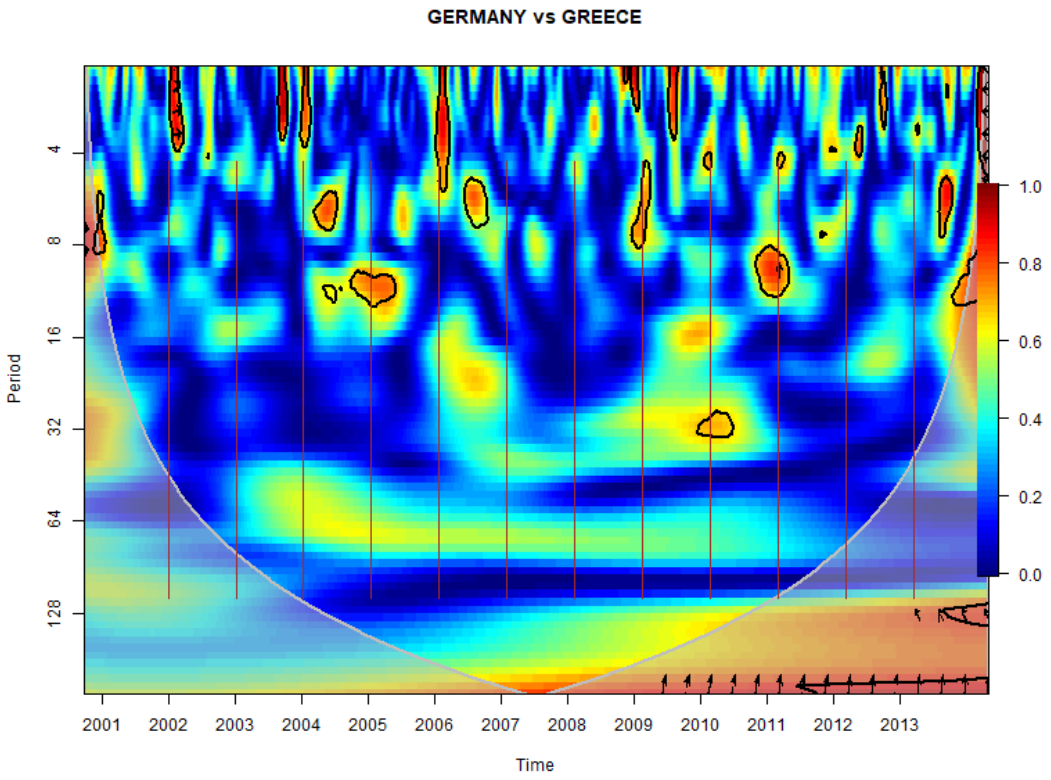
The wavelet coherence analysis shows limited short-term co-movements, with some localized activity in the early 2000s. A strong and persistent long-term co-movement is evident from approximately 2004 to 2012, with arrows predominantly pointing to the right, indicating a stable in-phase relationship between the two variables over this period.

Figure 24



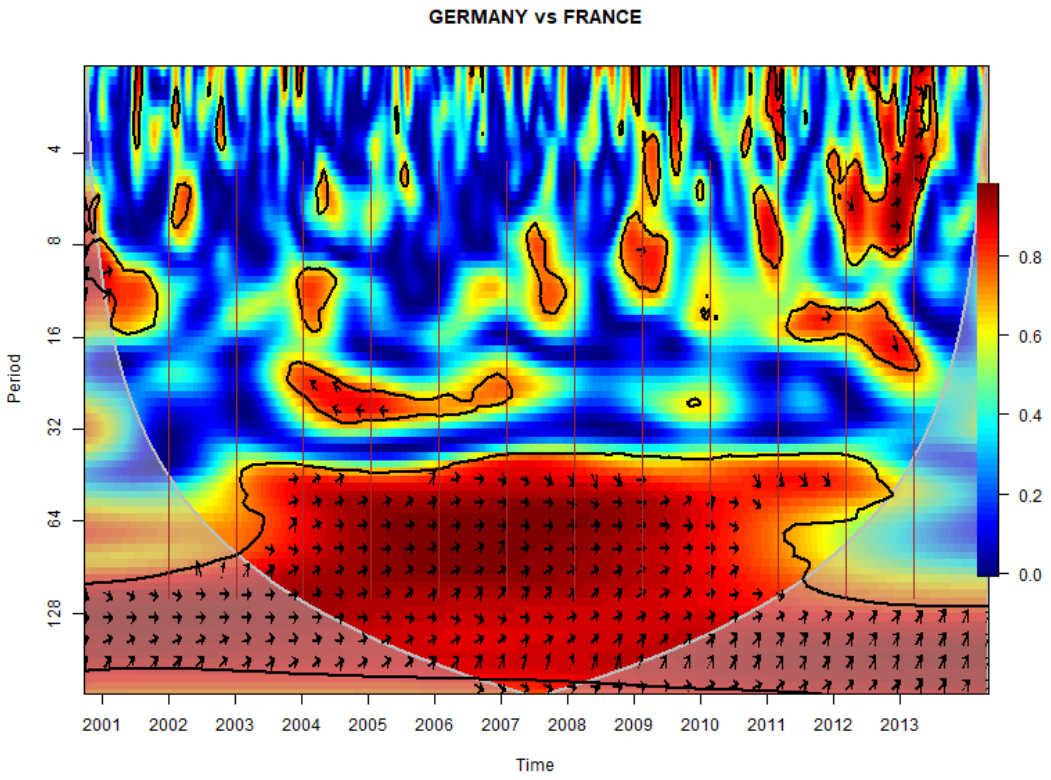
The wavelet coherence analysis indicates weak and scattered short-term co-movements, with no consistent patterns over time. A modest long-term co-movement emerges from around 2011 to 2013, where arrows predominantly point to the right, suggesting a developing in-phase relationship between the two variables during the final years of the sample period.

Figure 25



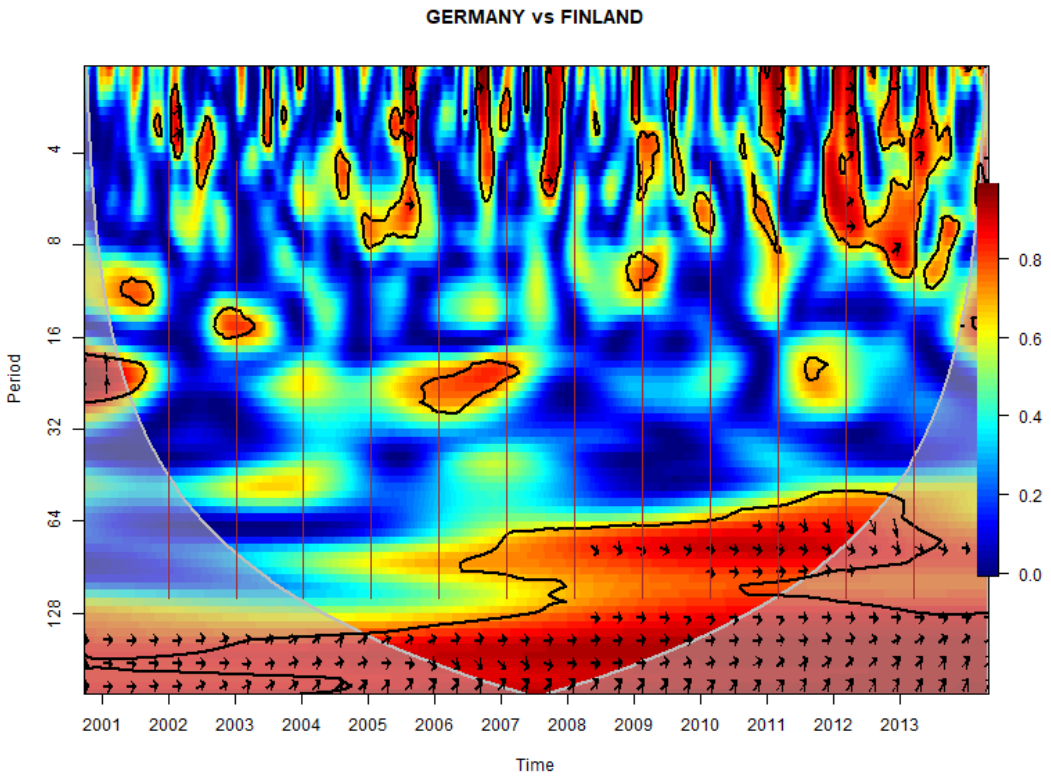
The wavelet coherence analysis reveals very limited short-term co-movement, with only a few weak and isolated episodes. A faint long-term co-movement begins to emerge toward the end of the sample period, around 2012–2013. During this time, arrows point mostly to the right, indicating the onset of an in-phase relationship between the two variables.

Figure 26



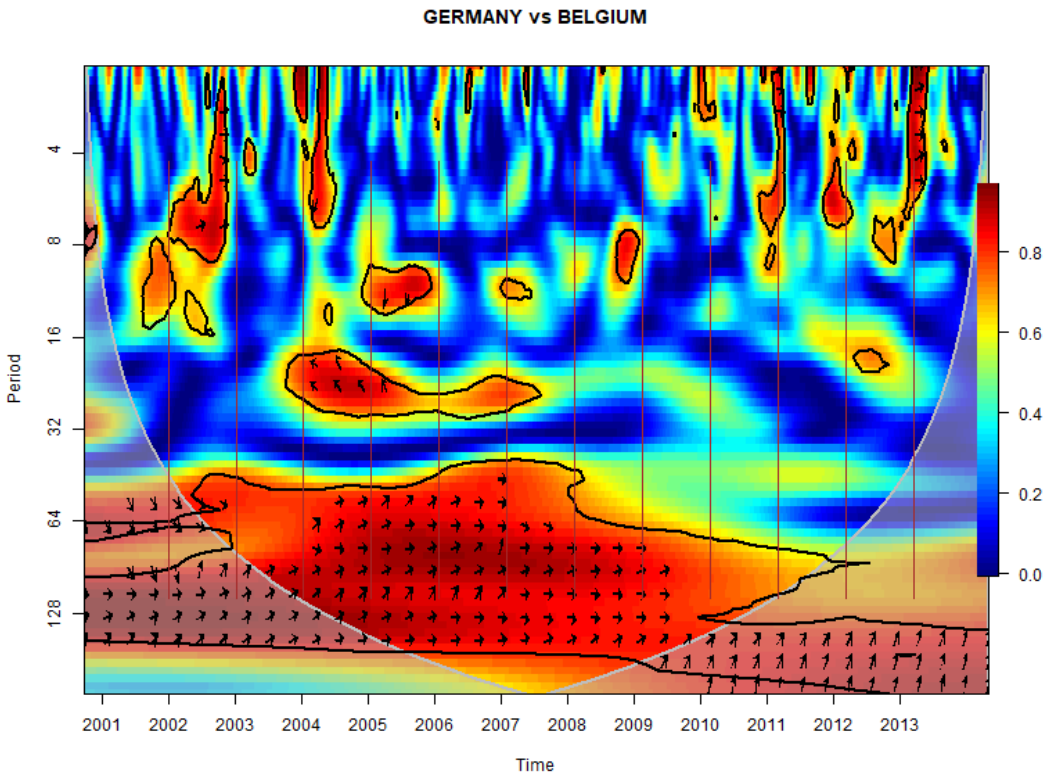
The wavelet coherence analysis reveals intermittent short-term co-movements, particularly around 2003 and 2005. A strong and persistent long-term co-movement is observed from approximately 2004 to 2012, with arrows predominantly pointing to the right, indicating a stable in-phase relationship between the two variables during this period.

Figure 27



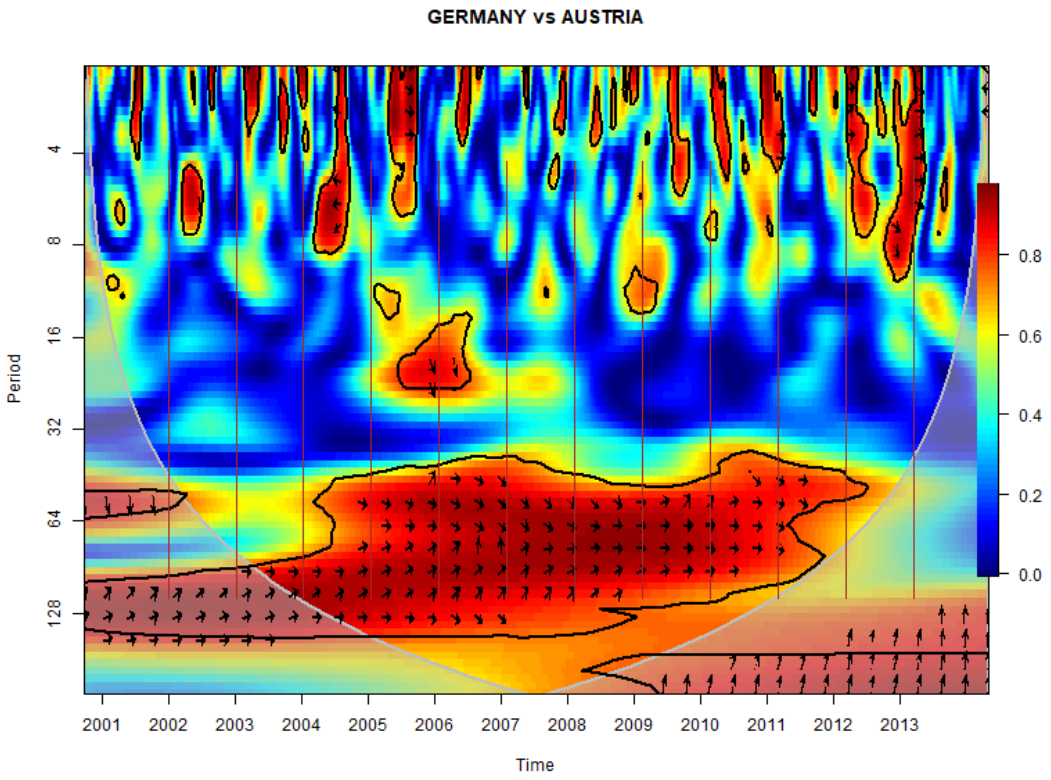
The wavelet coherence analysis indicates limited short-term co-movements, with only isolated episodes of significance. A strong and sustained long-term co-movement emerges from approximately 2007 to 2013. During this period, arrows predominantly point to the right, indicating a consistent in-phase relationship between the two variables.

Figure 28



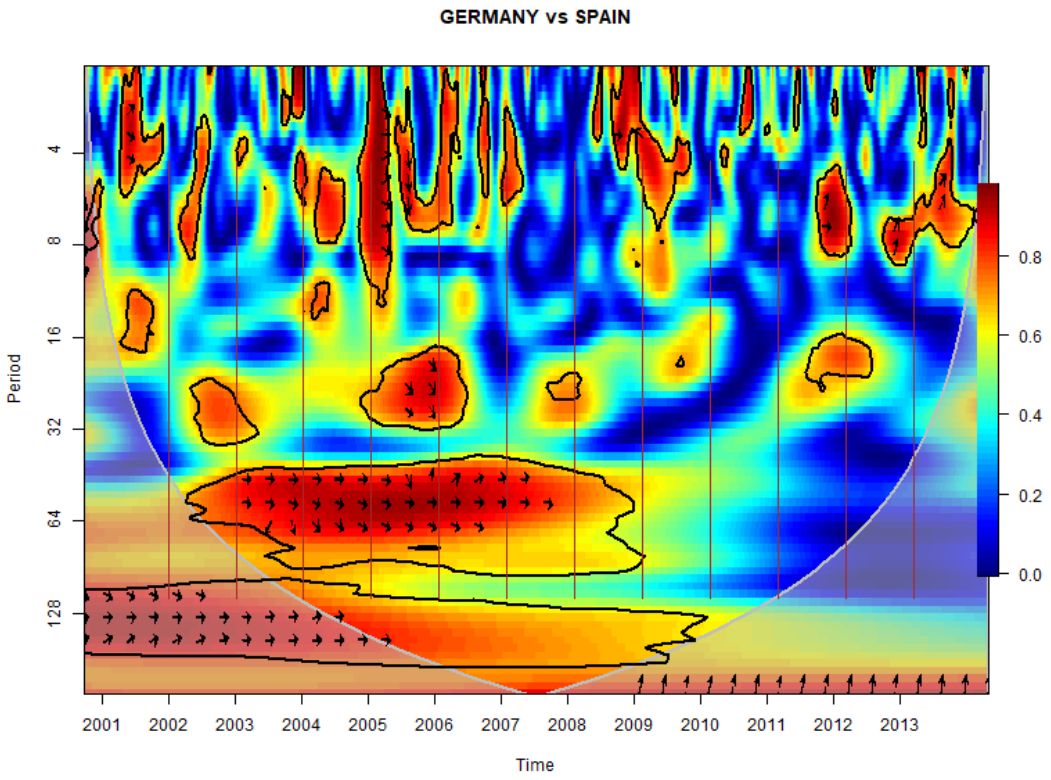
The wavelet coherence analysis reveals some short-term co-movements in the early 2000s, though they are relatively limited in duration and intensity. A strong and persistent long-term co-movement is evident from approximately 2004 to 2012, with arrows consistently pointing to the right, indicating a stable in-phase relationship between the two variables throughout this period.

Figure 29



The wavelet coherence analysis indicates minimal short-term co-movements, with only sporadic episodes in the early 2000s. A strong and persistent long-term co-movement is observed from approximately 2004 to 2012, with arrows predominantly pointing to the right, reflecting a consistent in-phase relationship between the two variables during this period.

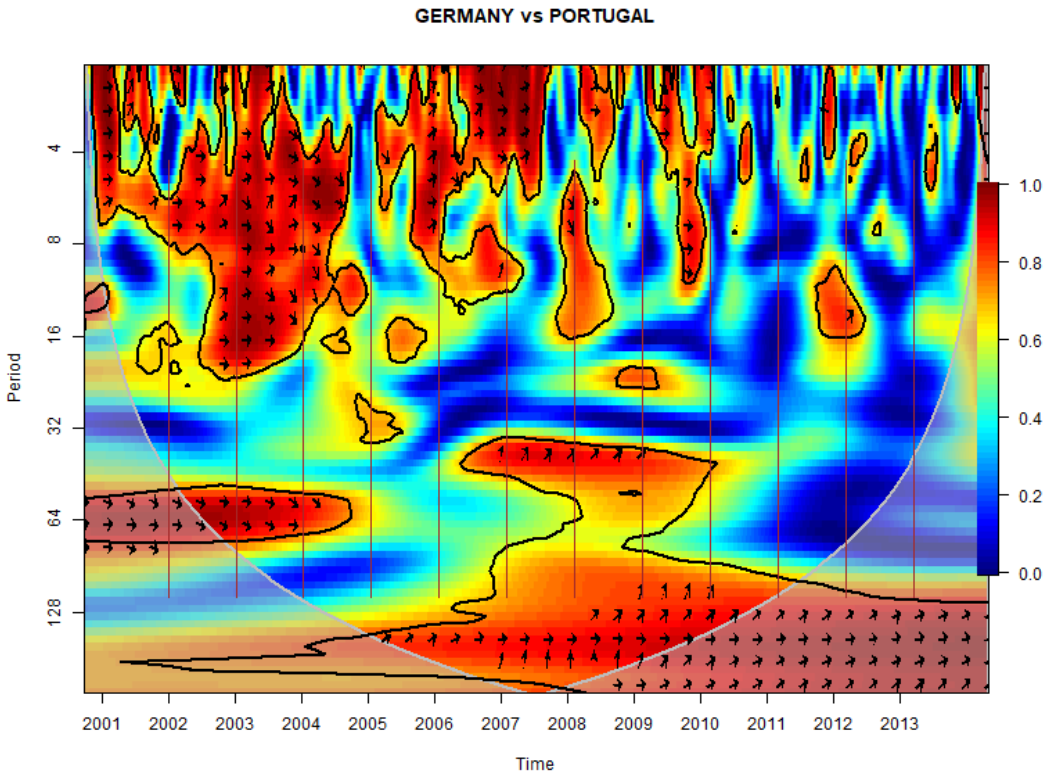
Figure 30



The wavelet coherence analysis reveals sporadic short-term co-movements, particularly between 2002 and 2004. A strong and sustained long-term co-movement is observed from approximately 2003 to 2009, with arrows predominantly pointing to the right, indicating a stable in-phase relationship between the two variables over this period.

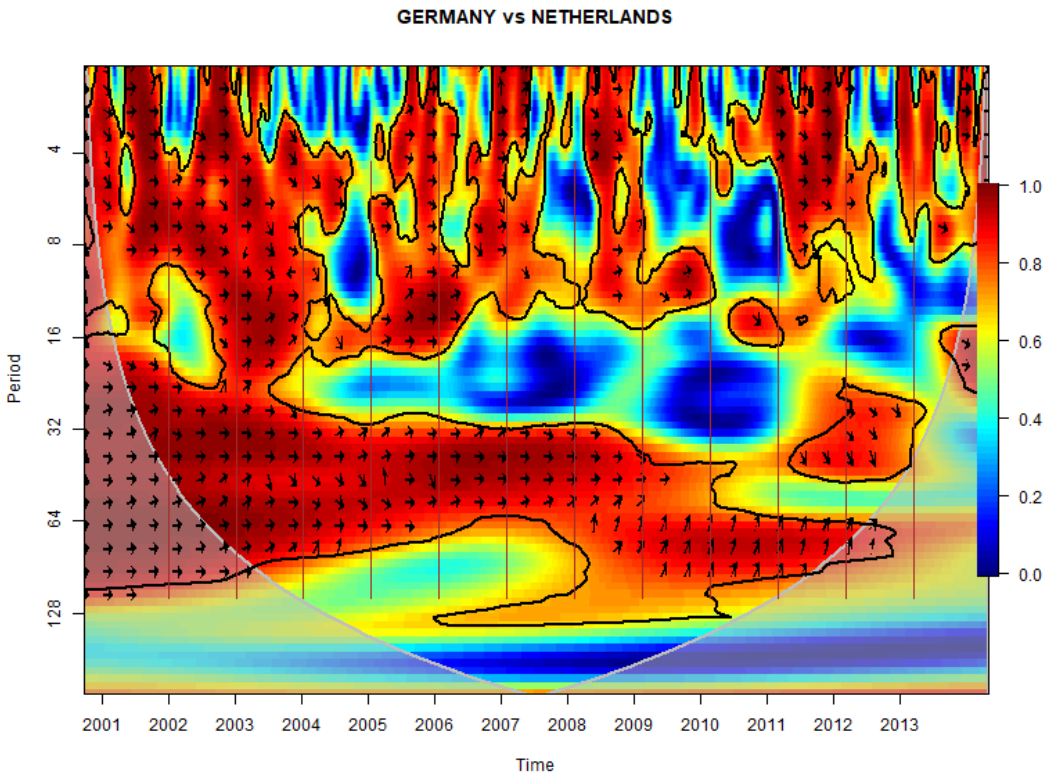
4.4 Money Stress Index

Figure 31



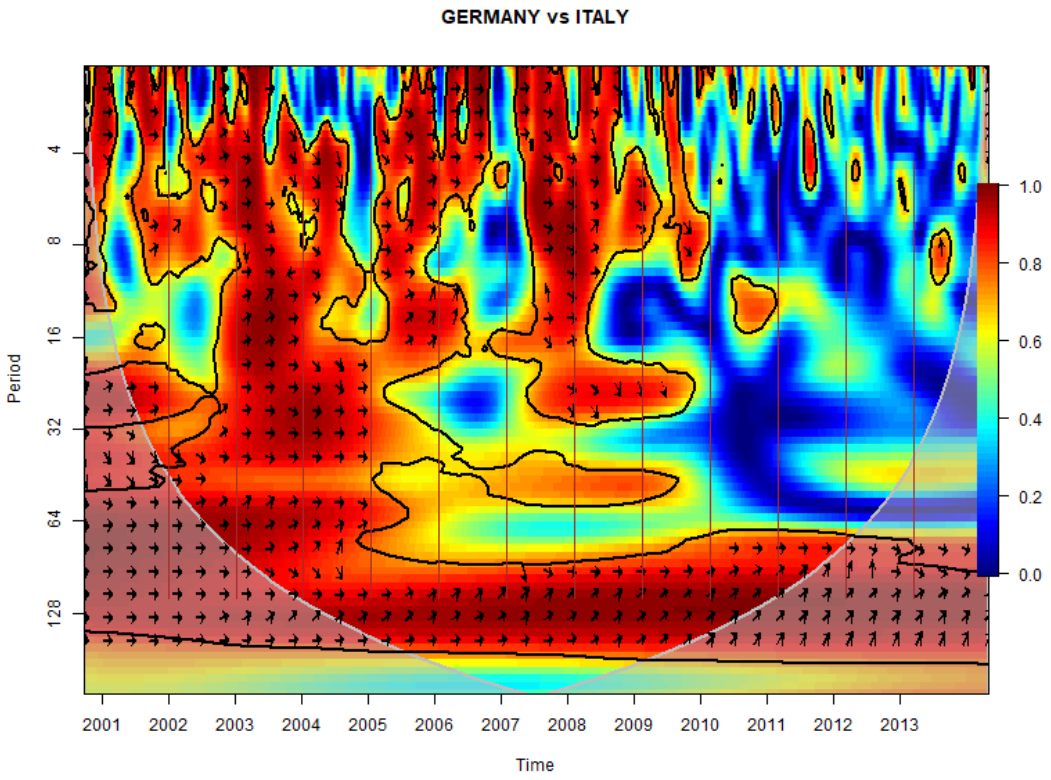
The wavelet coherence analysis reveals significant short-term co-movements between 2002 and 2004. A strong and persistent long-term co-movement develops from approximately 2007 to 2012, with arrows predominantly pointing to the right, indicating a stable in-phase relationship between the two variables during this period.

Figure 32



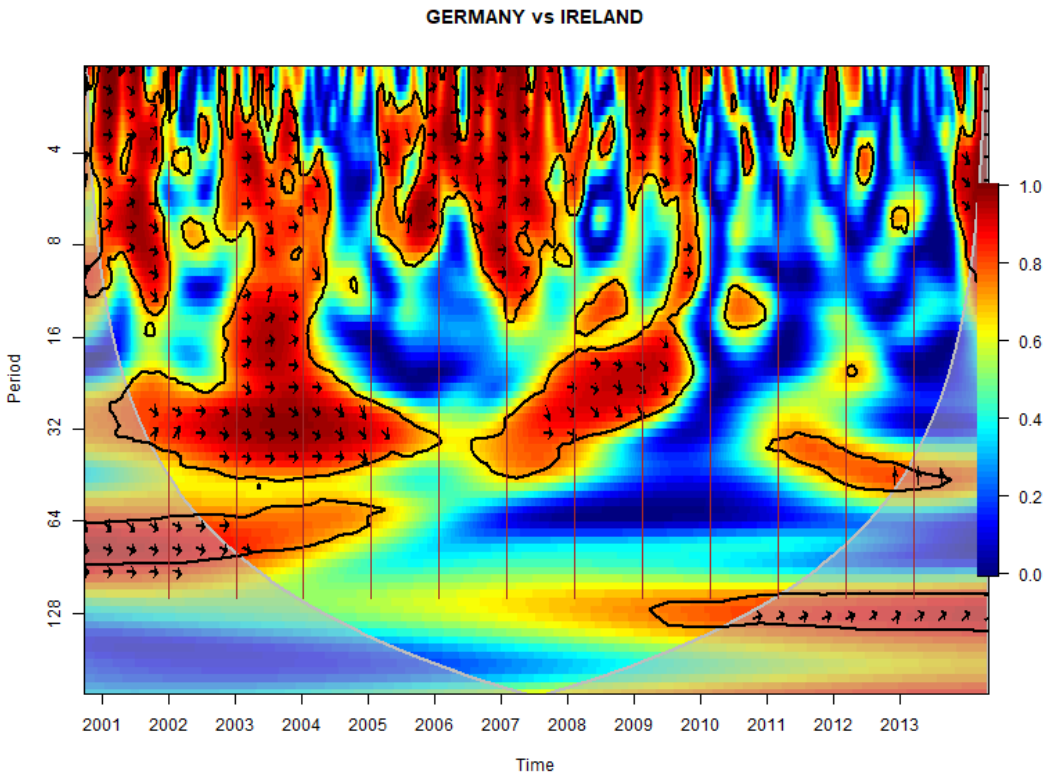
The wavelet coherence analysis reveals strong and persistent short-term co-movements across nearly the entire sample period, especially in long term period. In the long term, a pronounced co-movement is evident from approximately 2003 to 2012. Throughout both horizons, arrows predominantly point to the right, indicating a consistently strong in-phase relationship between the two variables.

Figure 33



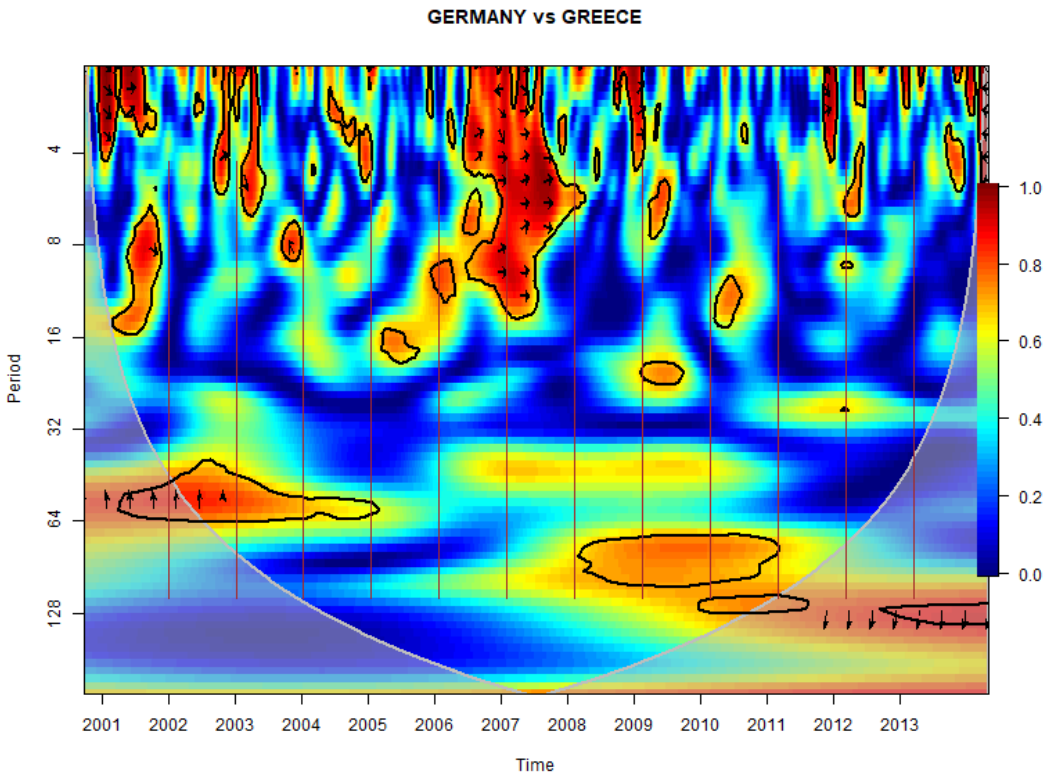
The wavelet coherence analysis reveals frequent and intense short-term co-movements from 2001 to 2009, particularly in long term period. A strong and persistent long-term co-movement is also observed from approximately 2003 to 2012, with arrows consistently pointing to the right, indicating a robust and sustained in-phase relationship between the two variables throughout this period.

Figure 34



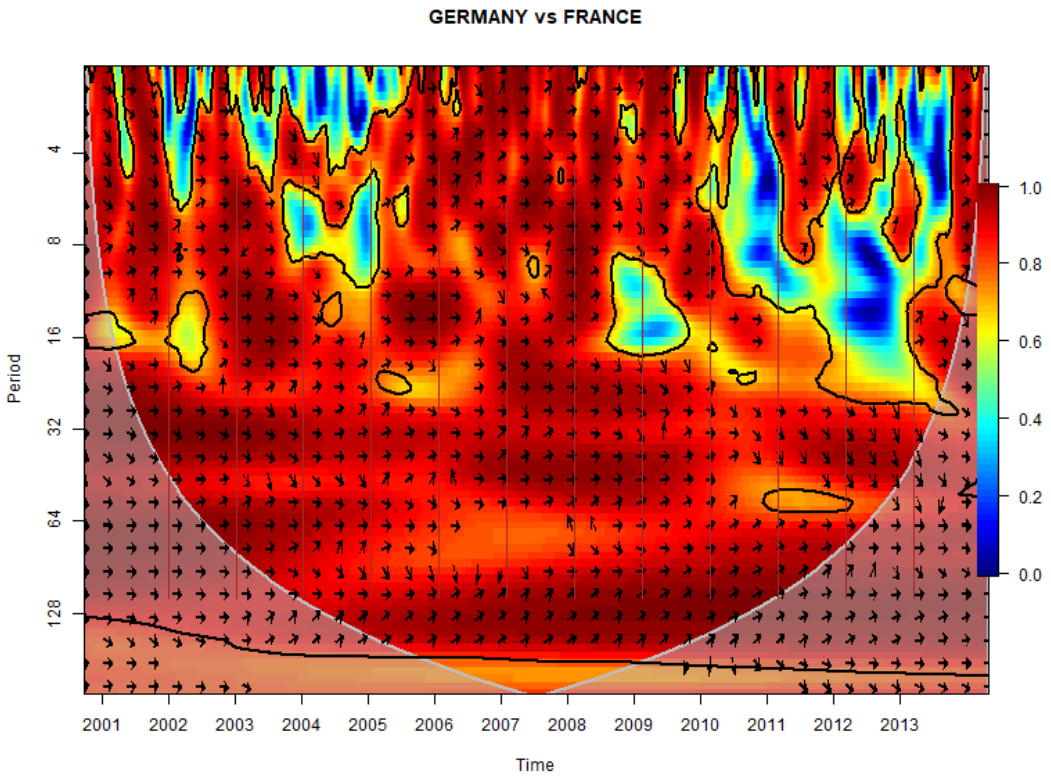
The wavelet coherence analysis reveals significant short-term co-movements from 2002 to 2007, especially in the higher-frequency range. A weaker but still evident long-term co-movement emerges from around 2011 to 2013, with arrows primarily pointing to the right, indicating a developing in-phase relationship between the two variables during this later period.

Figure 35



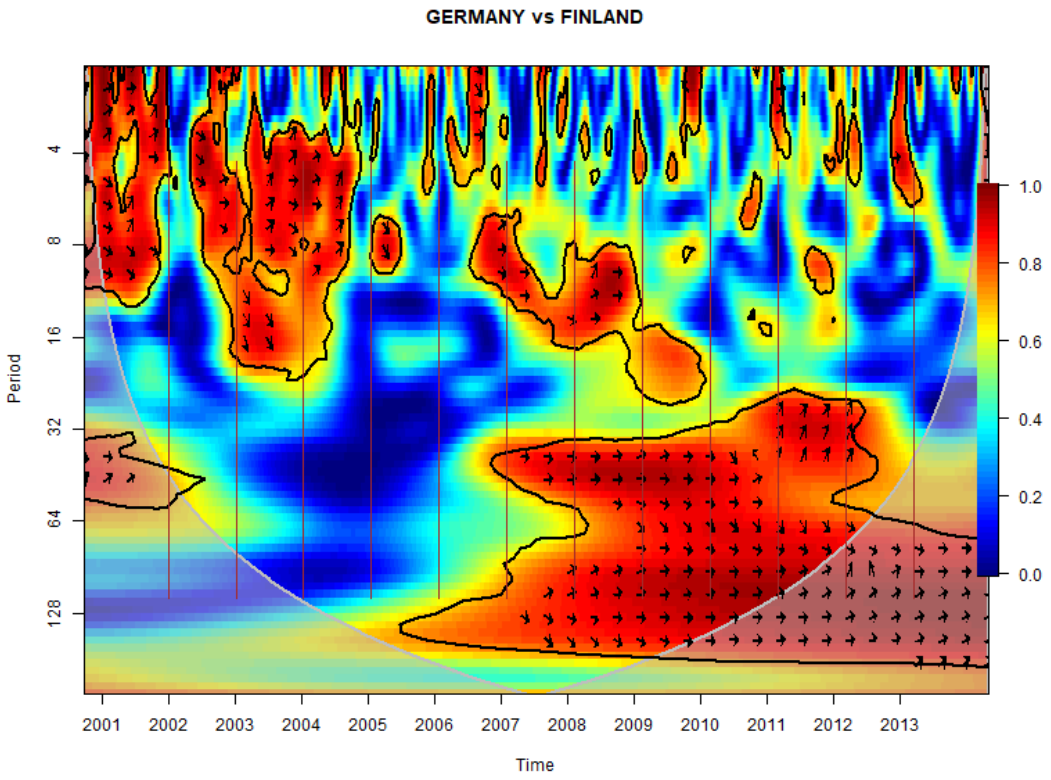
The wavelet coherence analysis reveals limited short-term co-movements, with only a few brief and scattered episodes. A weak and sporadic long-term co-movement emerges in the periods around 2002–2003 and again from 2011 to 2013. During these intervals, arrows tend to point to the right, indicating the presence of occasional in-phase relationships between the two variables.

Figure 36



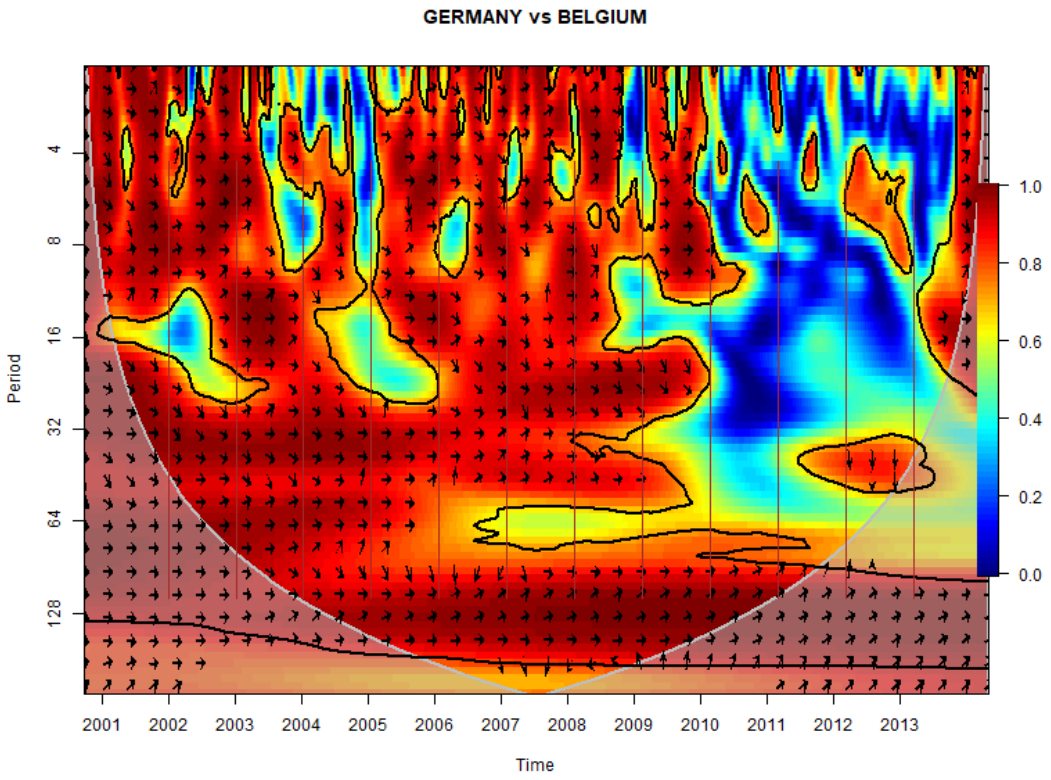
The wavelet coherence analysis indicates a strong and pervasive co-movement across both short- and long-term frequencies throughout nearly the entire sample period. From 2001 to 2013, the coherence remains consistently high, particularly in the short term period. arrows predominantly point to the right, reflecting a sustained and robust in-phase relationship between the two variables.

Figure 37



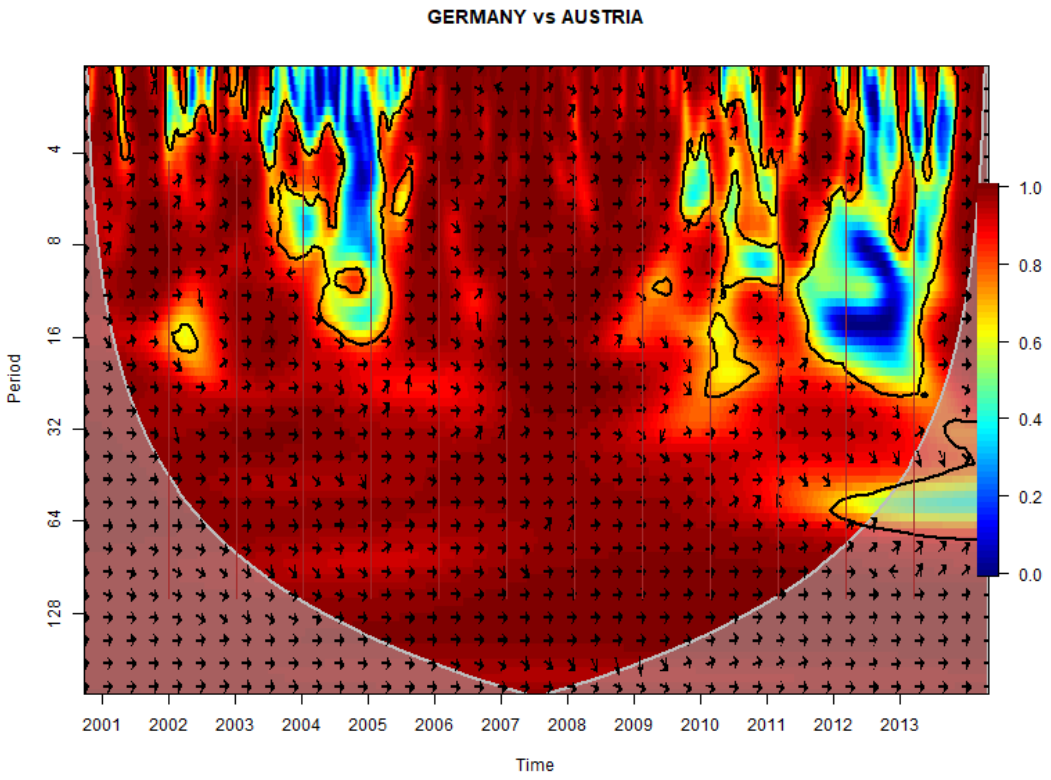
The wavelet coherence analysis indicates a strong and pervasive co-movement across both short- and long-term frequencies throughout nearly the entire sample period. From 2001 to 2013, the coherence remains consistently high, particularly in short term period. Arrows predominantly point to the right, reflecting a sustained and robust in-phase relationship between the two variables.

Figure 38



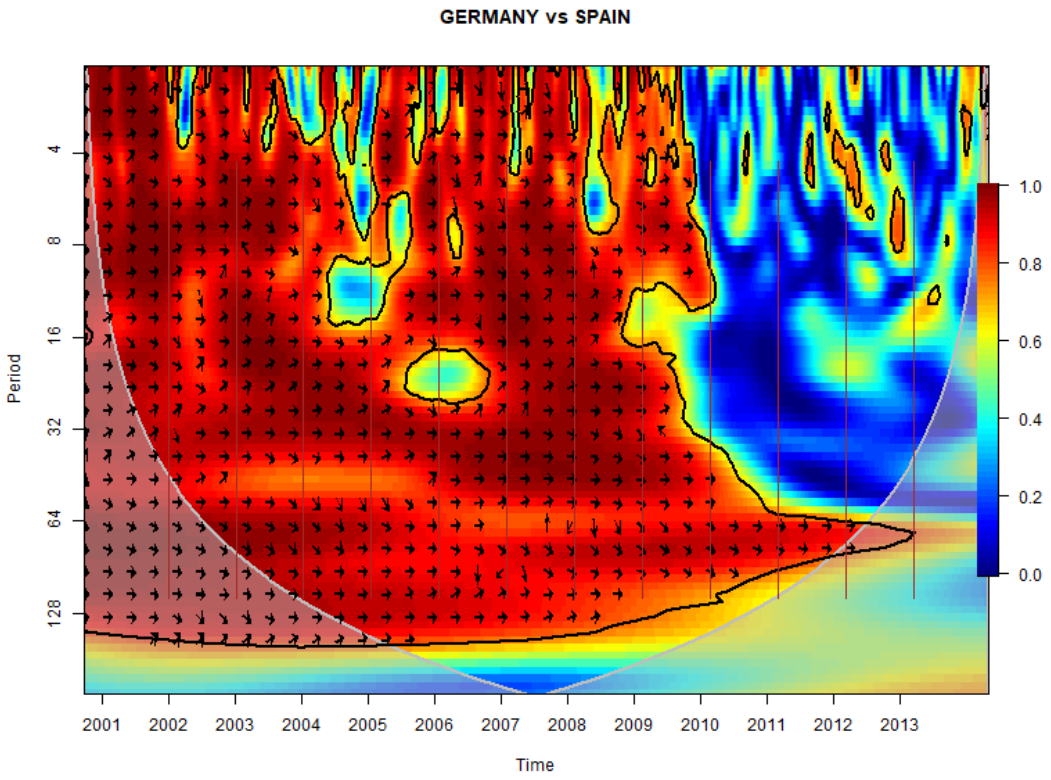
The wavelet coherence analysis demonstrates a consistently high level of co-movement across both short- and long-term frequencies from 2001 to approximately 2010. The coherence remains particularly strong in the low-frequency range, reflecting a robust long-term in-phase relationship, as indicated by the right-pointing phase arrows. A decline in coherence is observed after 2010, particularly in long term period.

Figure 39



The wavelet coherence analysis indicates an exceptionally high and persistent level of co-movement across nearly all frequencies and over the entire sample period. The dominance of red regions, combined with consistently right-pointing phase arrows, reflects a strong and stable in-phase relationship between the two variables, both in the short and long term.

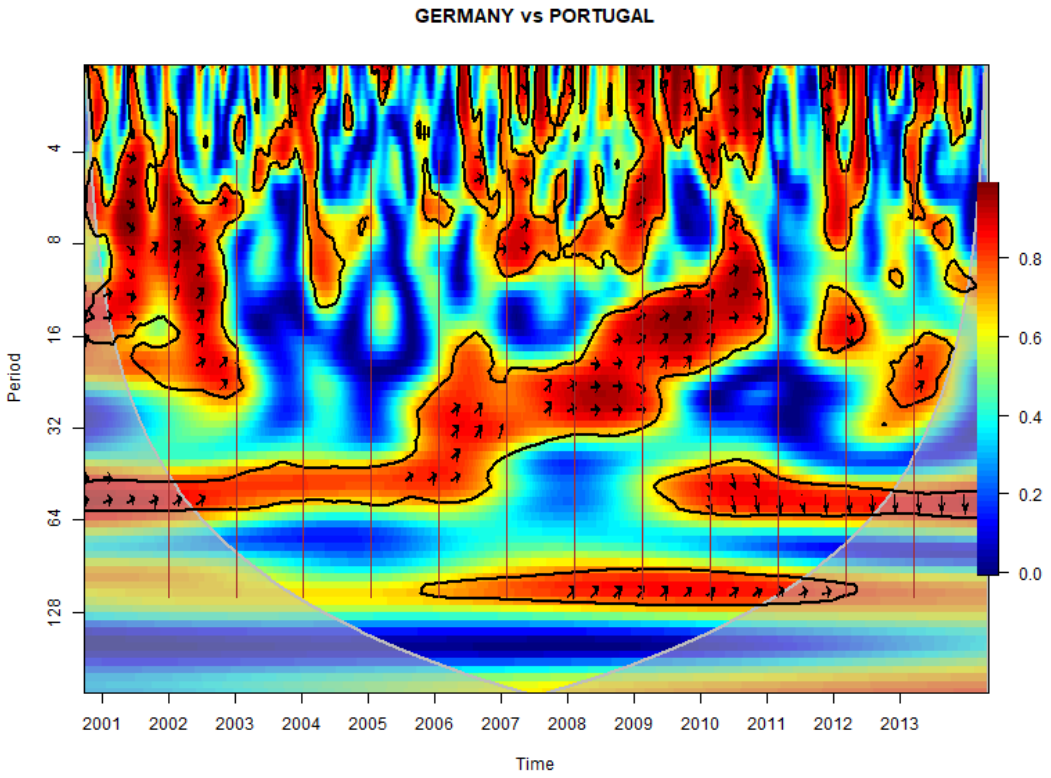
Figure 40



The wavelet coherence analysis exhibits strong and sustained co-movement from approximately 2002 to 2011 across both short- and long-term frequencies. This is evidenced by the extensive red regions and consistently right-pointing arrows, indicating a stable and robust in-phase relationship between the two variables over that period. A notable decline in coherence is observed after 2011.

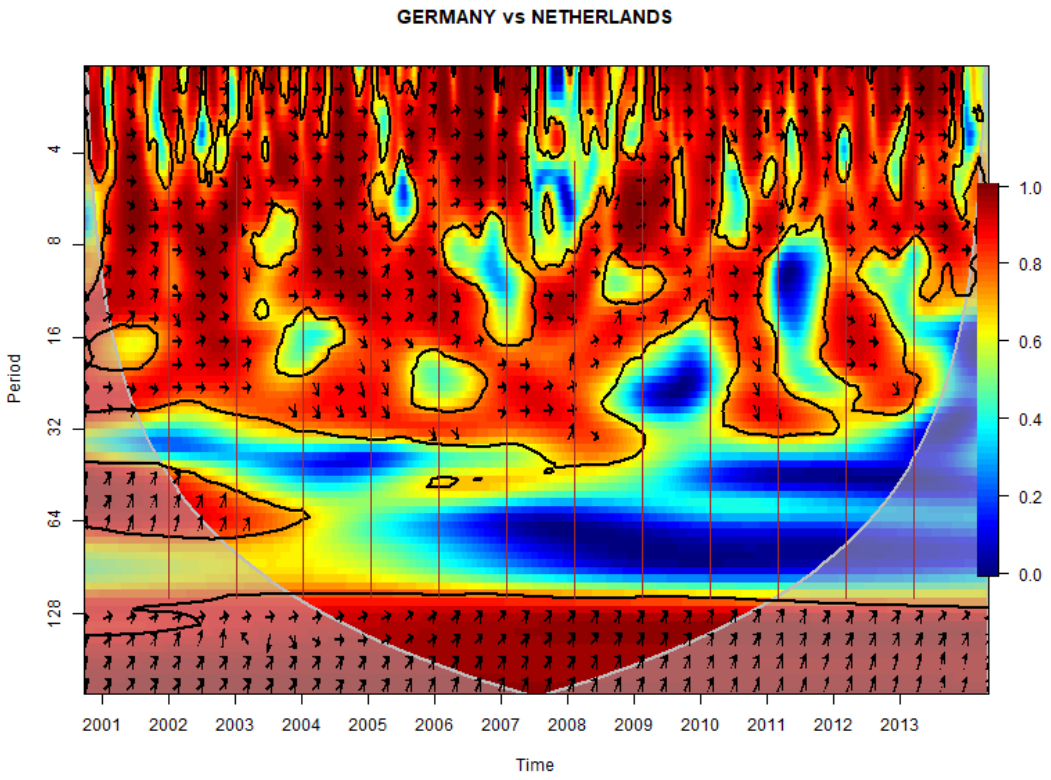
4.5 Stocks Stress Index

Figure 41



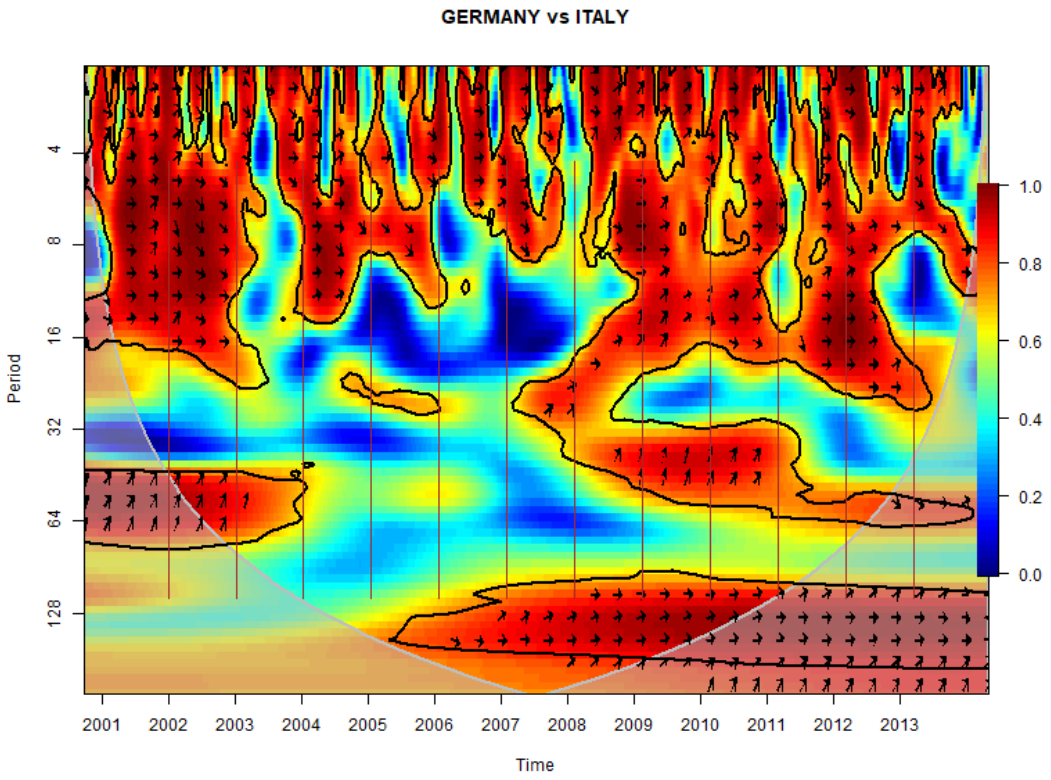
The wavelet coherence analysis reveals moderate to strong co-movement episodes, particularly between 2002 and 2004 at lower frequencies and again from 2007 to 2011 across both medium- and long-term frequencies. During these intervals, the arrows predominantly point to the right, indicating an in-phase relationship. While some coherence persists through to 2013, it is comparatively weaker and more fragmented.

Figure 42



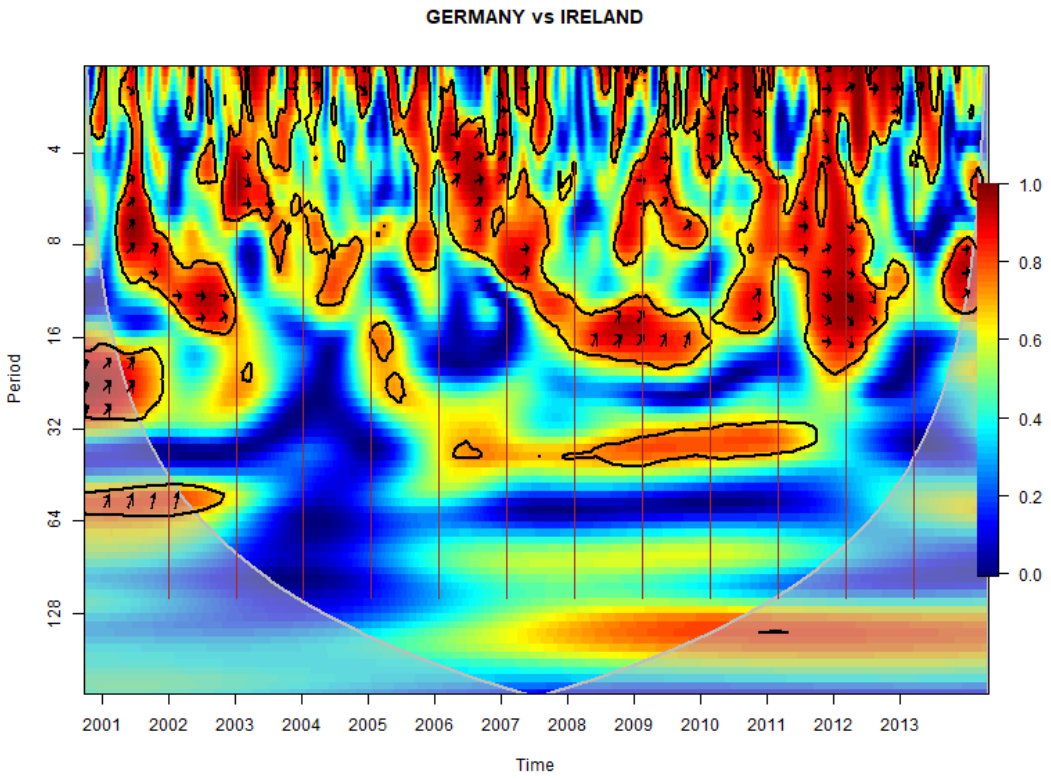
The wavelet coherence plot indicates a sustained and robust co-movement at low frequencies (long-term periodicities) from approximately 2003 to 2012, as evidenced by the consistently high coherence (deep red areas) in the bottom half of the cone of influence. The arrows predominantly point to the right, suggesting an in-phase relationship between the two variables during this interval. Higher frequency interactions appear weaker and more intermittent, with notable coherence pockets between 2005 and 2008. Overall, the relationship demonstrates both persistence and synchronicity, especially in the long-term trend.

Figure 43



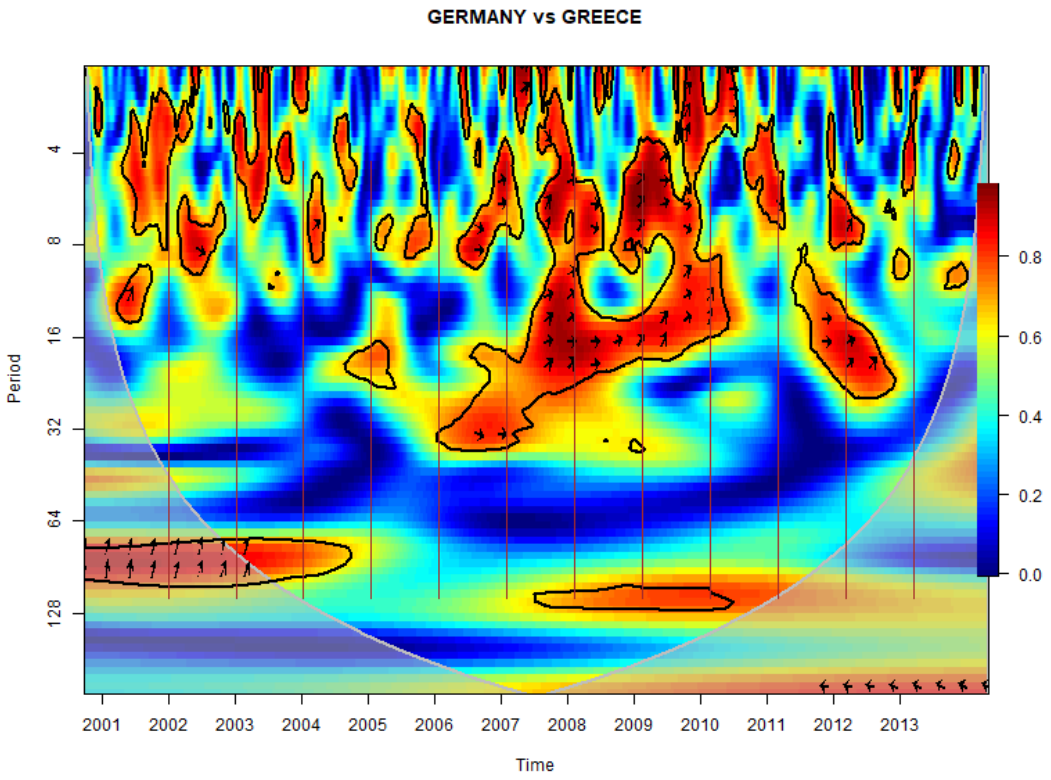
This wavelet coherence plot reveals a significant long-term co-movement between the two variables particularly from 2006 to 2012, shown by the pronounced red area at low frequencies (higher periods). The coherence is strongest in long term period, and the arrows in these regions generally point rightward, indicating an in-phase relationship, where both variables tend to rise and fall together.

Figure 44



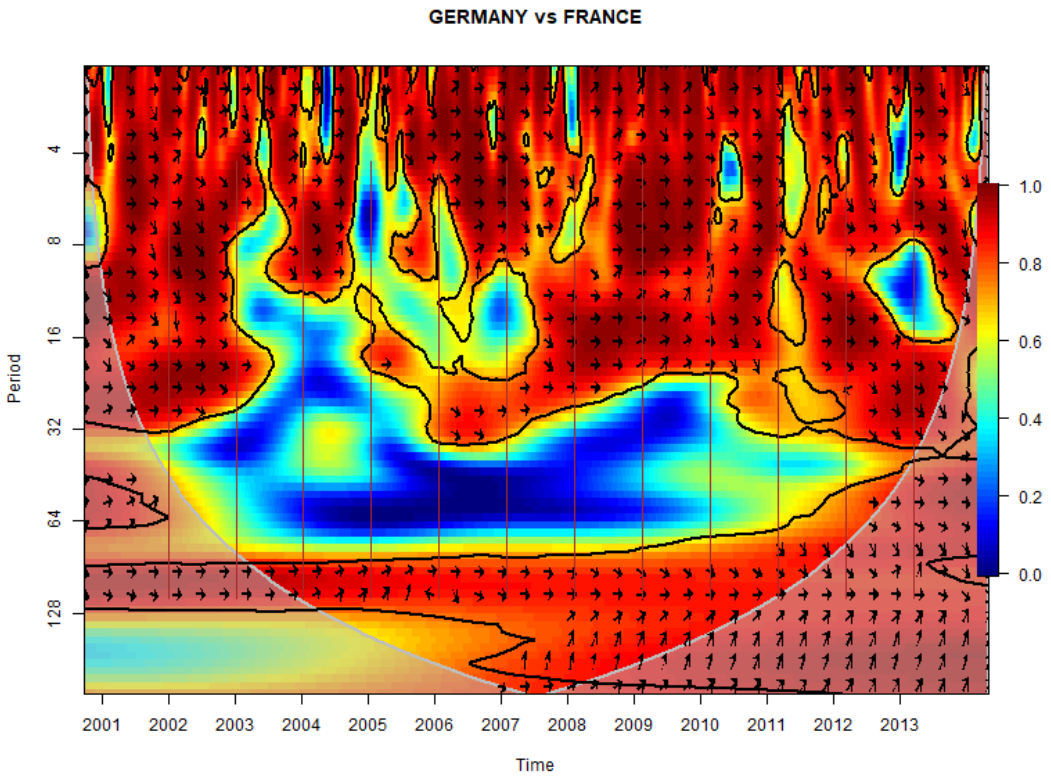
The wavelet coherence plot exhibits significant coherence at lower frequencies (periods around 64–128) from mid-2007 to 2012. This suggests a strong long-term relationship during this period, with Germany leading the dynamic, as indicated by the rightward-pointing arrows. Prior to this, coherence is fragmented and largely insignificant.

Figure 45



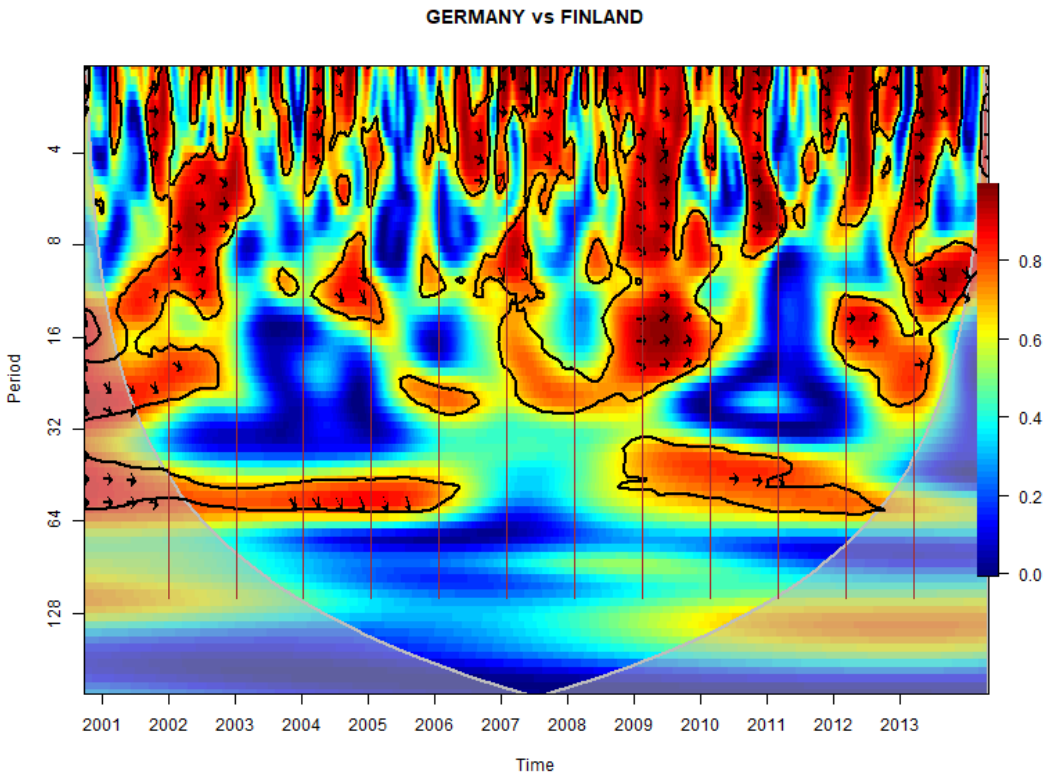
The plot reveals a clear short-term relationship during the 2007–2011 period, with consistent and strong coherence. There is also some evidence of a long-term association starting around 2008, persisting through 2011, where the first series appears to lead. A smaller, earlier short-term connection is noticeable around 2003–2004, though it is more localized.

Figure 46



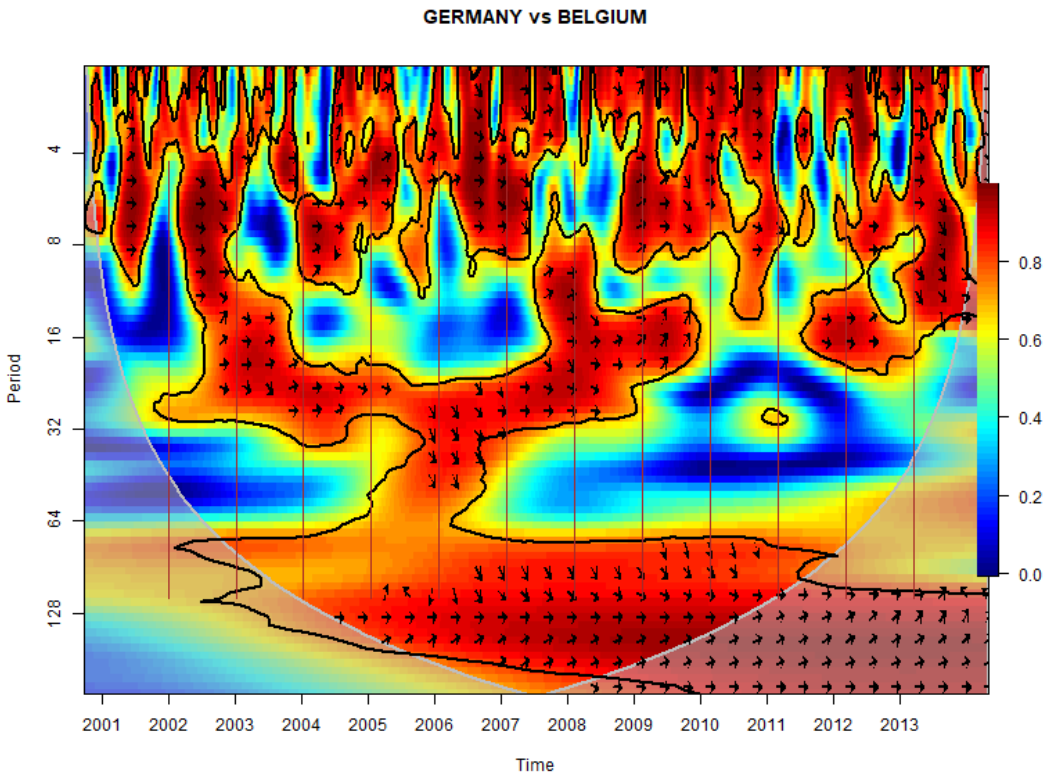
This plot shows a pronounced long-term relationship from around 2006 to 2012, with strong coherence and clear directional consistency. Short-term coherence is also evident in scattered patches before and after this period, though less consistently. The leading direction remains fairly stable throughout the long-term interval.

Figure 47



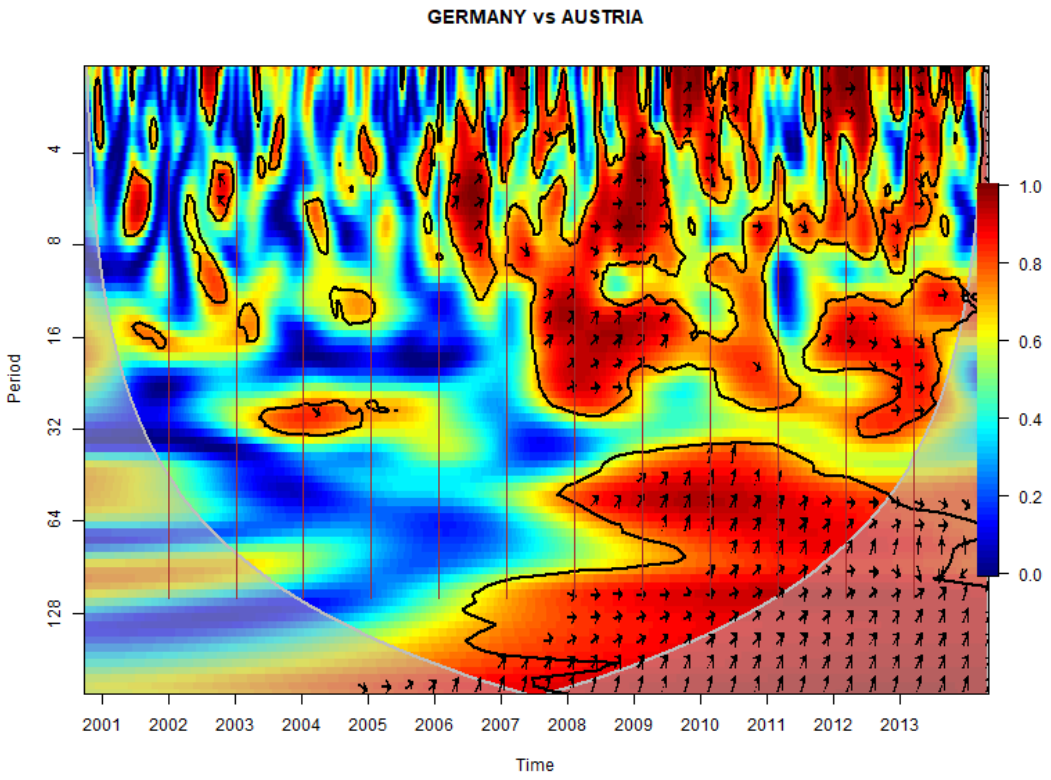
This plot displays clear short-term coherence occurring intermittently throughout the timeline, particularly in the early 2000s and around 2009–2011. There is no persistent long-term coherence, though a few weaker long-term patterns appear briefly and are less consistent in directionality.

Figure 48



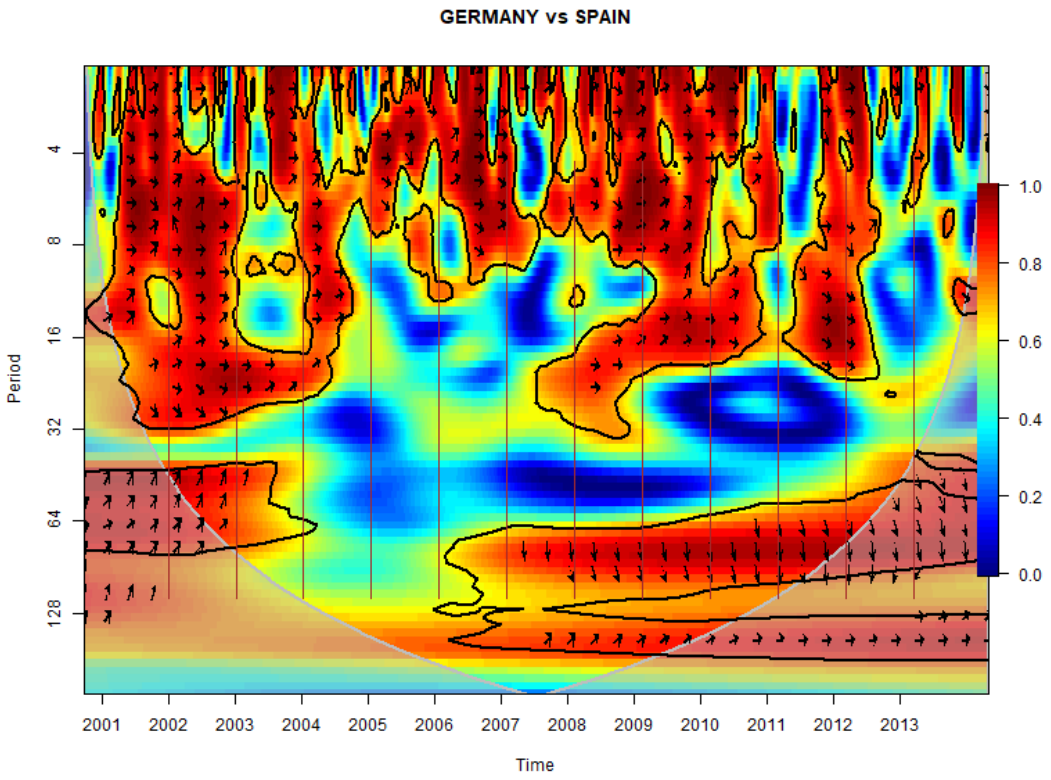
This plot shows strong and sustained long-term coherence beginning around 2005 and continuing through to 2012. There is also notable short-term coherence occurring sporadically throughout the entire period, particularly before 2005. Arrows in both regions are relatively consistent in direction, indicating stable phase relationships.

Figure 49



This plot highlights strong long-term coherence from around 2007 through 2013, with a clearly defined and persistent region of high correlation. Short-term coherence is present but scattered, with smaller patches occurring mostly in the earlier years. The direction of the arrows in the long-term period remains consistent, suggesting a stable and steady phase relationship over time.

Figure 50



This plot reveals notable long-term coherence beginning around 2008 and continuing through 2013, with a clear, sustained region of high power. The direction of the arrows indicates a consistent phase relationship. Short-term coherence appears intermittently in the upper region, mostly between 2002 and 2007, but is less stable and more fragmented compared to the long-term signal.

Conclusions

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