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FINANCIAL INTEGRATION OF THE EUROPEAN UNION FINANCIAL MARKETS. A PCA APPROACH

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Abstract:

European stock markets are a complex and dynamic terrain, requiring sophisticated methods of analysis to understand their degree of interconnectedness and integration. The paper investigates the financial integration of European Union (EU) financial markets using a dynamic Principal Component Analysis (PCA) approach. By calculating the Financial Integration Index (FII) from daily stock market index returns and volatilities, we provide a comprehensive analysis of the integration trends over the past two decades across three distinct groups: the EU-27, the Eurozone, and the Non-Eurozone emerging economies. Our findings indicate an increased evolution of financial integration for all groups, with the Eurozone and Non-Eurozone groups exhibiting higher levels of financial integration compared to the broader EU-27. The results highlight that major crises significantly influence the dynamics of financial integration. Finally, the study underscores the higher sensitivity of volatility-based FII compared to return-based FII, making it a more effective measure for real-time monitoring of financial market integration. Our findings have several important implications for policymakers, which should monitor volatility closely as an early warning indicator of financial distress, and for portfolio managers, which have to consider both returns and volatility when assessing international portfolio diversification strategies.

Key words: Principal Component Analysis (PCA), Financial integration, Cohesion, European Union stock markets

1. Introduction

European financial markets are becoming increasingly integrated, significantly impacting investment and financing decisions by both institutional and private investors. The perceived degree of integration across these markets influences asset allocation strategies. Consequently, financial integration has garnered substantial attention in the literature, with a significant focus on its implications for asset allocation within the context of European financial cohesion and stability.

The financial integration of the European Union's (EU) financial markets has been a fundamental objective of the EU since its inception. The creation of a single market aims to

facilitate the free movement of capital, enhance economic stability, and promote growth across member states. Financial integration is defined as the process by which financial markets in different geographical areas become more closely interconnected, enabling investors to diversify their portfolios more effectively and businesses to access a wider range of funding sources. The European Commission has consistently emphasized the importance of financial integration as a key driver for economic convergence and resilience. Despite significant progress, the EU financial markets still face challenges in achieving full integration due to regulatory differences, market fragmentation, and varying levels of development across member states.

The integration of financial markets, particularly stock markets, is a vital area of study due to its numerous practical implications, especially concerning international portfolio selection and diversification. Portfolio theory suggests that the benefits and motivations for international diversification hinge on maintaining low correlations among global equity markets. Low correlations between foreign and domestic stock market returns enable investors to reduce portfolio risk while preserving expected returns by incorporating foreign assets into their domestic portfolios. However, a high level of financial integration often leads to increased cross-market correlations, which can significantly diminish the advantages of cross-border portfolio diversification.

Research has indicated that the degree of financial integration across markets fluctuates over time, with evidence pointing towards increasing integration of capital markets. This growing international financial integration has significant implications for economic theory and policy discussions. While integrated financial markets benefit from easier access to foreign capital, they also become more susceptible to global events, such as financial crises. The causes and effects of the Global Financial Crisis (GFC) are closely linked to the international financial integration between markets.

The transmission of the crisis through financial and banking channels was both swift and significant. Pisani-Ferry and Sapir (2010) highlight that European banks were especially susceptible due to the high level of internationalization in their operations, both within and beyond the euro area. Simultaneously, the degree of financial integration among European financial markets, including the emerging markets of Central and Eastern Europe (CEE), increased considerably during the critical period of the Global Financial Crisis (GFC). Another event that had a significant impact on the financial integration of European markets was the COVID-19 pandemic. The outbreak in early 2020 led to unprecedented economic disruptions and market volatility globally. Goldstein et al. (2021) observed that European financial markets experienced substantial fluctuations, with stock indices plummeting initially, followed by a recovery period as governments and central banks implemented extensive fiscal and monetary interventions. The pandemic underscored the interconnectedness of global financial systems and highlighted the vulnerabilities associated with such integration. Despite these challenges, the crisis also demonstrated the resilience of integrated financial markets and accelerated the digital transformation in the financial sector, potentially reshaping the landscape of financial integration in the long term.

Given that the degree of international market integration fluctuates over time, it is crucial to conduct a deeper investigation into the dynamics of this process. Therefore, the

primary goal of the paper is to assess the evolution of the financial integration process across three distinct groups of countries within the European Union: the EU-27, the Eurozone, and the non-Euro emerging economies (Bulgaria, Czech Republic, Hungary, Poland, and Romania). Utilizing a dynamic principal component analysis (PCA) approach, we calculate the Financial Integration Index (FII) as the percentage of variance explained by the first principal component, following the methodology outlined by Volosovych (2011, 2013). This analysis spans the last two decades, providing a comprehensive overview of the integration trends over this period.

Secondly, in contrast to existing studies that typically employ PCA using exclusively daily stock market index returns, our approach innovatively incorporates both daily stock market index returns and volatilities. We aim to determine which measure—return or volatility—serves as a more efficient and sensitive indicator of financial integration. This dual-faceted approach allows for a deeper understanding of the interconnectedness and cohesion within European financial markets.

The ultimate goal is to investigate the impact of turbulent periods on the dynamics of the Financial Integration Index. Specifically, we analyze how major economic disruptions, such as the Global Financial Crisis, the European Sovereign Debt Crisis, and the COVID-19 pandemic, have influenced the degree of financial integration among the selected groups. This examination provides valuable insights into the resilience and adaptability of European financial markets in the face of significant economic challenges.

The remaining of the paper is arranged as follows: Section 2 presents a review of recent studies addressing the subject of financial integration, Section 3 outlines the data and methodological approach used in the paper. Section 4 describes the research findings and discusses their implications, whereas Section 5 concludes the paper.

2. Literature review

Financial integration is a multifaceted concept with no single accepted definition in the literature. Hardouvelis et al. (2006) highlight that partially integrated stock markets take into account both global and local risk factors. In contrast, Pukthuanthong and Roll (2009) point out the discrepancy between intuitive perceptions and quantitative measures of integration. Bekaert and Harvey (1995) propose that markets are fully integrated if assets with identical risk levels have the same expected returns, reflecting exposure to global factors. On the other hand, segmented markets exhibit little or no covariance with global factors in explaining expected returns. Bekaert et al. (2005) add that integration can occur on either a regional or global scale.

Obstfeld and Taylor (2003) provide a historical perspective, tracing capital mobility from 1860 to 2000 and revealing a U-shaped trend in global capital market integration. Donadelli and Paradiso (2014) extend this by exploring the diverse dynamics of financial integration across emerging regions, identifying three patterns: a consistent upward trend, a J-shaped trend, and a U-shaped trend. Most researchers agree that financial markets globally exhibit time-varying integration.

The relationship between trade openness and financial integration is explored by Beine et al. (2010), who argue that these elements are complementary rather than

substitutive. Chambet and Gibson (2008) support this by examining the impact of trade policies in emerging economies on financial integration, concluding that trade openness promotes financial integration.

Financial shocks significantly influence integration levels. Sachs et al. (1996) and Corsetti et al. (2005) highlight that increased co-movement in international equity market returns and volatility often results from contagion effects. For instance, Baig and Goldfajn (1999) and Chkili and Nguyen (2014) observed heightened correlation during the Asian and Russian crises, respectively. Majewska and Olbryś (2017) studied six European stock markets during the Global Financial Crisis (GFC), finding an inverted U-shaped pattern in integration levels: an increase during the crisis followed by a decline.

The 2004 accession of Central and Eastern European Countries (CEEC) to the European Union marked a significant step in enhancing financial integration. Olbryś and Majewska (2015) noted that post-accession, CEEC markets became more integrated with developed EU markets due to regulatory harmonization, increased cross-border capital flows, and improved investor confidence. Donadelli and Paradiso (2014) also reported a continual rise in equity market integration in Eastern Europe following EU enlargement.

Various methodologies have been employed to study financial integration within the European Union (EU). Kučerová (2009) analyzed the international investment positions of new EU member states to assess integration through capital movement. Bekaert et al. (2002) used a reduced-form econometric model to identify break points in financial time series, while Higson et al. (2013) utilized a nonlinear time-varying factor model to account for country-specific heterogeneity. Poddig and Rehkugler (1996) applied artificial neural networks (ANN) to develop a 'world' model of integrated financial markets.

Principal Component Analysis (PCA) is a prevalent method for studying financial integration. Volosovych (2013) applied PCA to examine the integration of capital markets across 15 industrialized economies from 1875 to 2009, and his earlier study (2011) used PCA to analyze sovereign bond data, revealing a J-shaped trend post-World War II. Donadelli and Paradiso (2014) employed dynamic PCA to measure integration across various regions and industries, uncovering significant sectoral differences.

3. Research methodology and data description

Principal Component Analysis (PCA) is a non-parametric statistical technique, used in data analysis and dimensionality reduction. It transforms a set of correlated variables into a set of values for linearly uncorrelated variables called principal components. These components are arranged in a certain sequence, with the first few components capturing the majority of the variation inherent in all of the original variables. This transformation is achieved through an orthogonal linear transformation.

Following the methodology outlined by Volosovych (2011), the paper employs a Principal Component Analysis (PCA), using a rolling window of 500 days to capture the dynamic nature of financial integration. We calculate the Financial Integration Index as the variance explained by the first principal component. We apply PCA using daily stock market index returns and, separately, daily stock market index volatilities.

The daily stock market index return is calculated as follows:

$$Return_t = Ln \left(\frac{P_t}{P_{t-1}} \right) \quad \text{Equation (1)}$$

Where:

P_t is the price at time t .

P_{t-1} is the price at time $t-1$.

As for the daily stock market index volatility, we use Garman-Klass Yang-Zhang Extension formula:

$$Volatility(\sigma^2) = \left(Ln \left(\frac{o_i}{c_{i-1}} \right) \right)^2 + \frac{1}{2} \left(Ln \left(\frac{h^i}{l^i} \right) \right)^2 - (2Ln(2) - 1) \left(Ln \left(\frac{c_i}{o_i} \right) \right)^2$$

Equation (2)

Where:

o_i is the opening price on day i .

c_{i-1} is the closing price on day $i-1$.

h^i is the highest price on day i .

l^i is the lowest price on day i .

c_i is the closing price on day i .

The data used in this analysis encompasses the daily values of major stock market indexes for the countries in the European Union over the period from January 2005 to April 2024.

Table 1. The European stock market indexes used in the paper

Country	Stock Market Index	Country	Stock Market Index	Country	Stock Market Index
Austria	ATX	France	CAC 40	Malta	MSE
Belgium	BEL 20	Germany	DAX	Netherlands	AEX
Bulgaria	SOFIX	Greece	ASE	Poland	WIG 20
Croatia	CROBEX	Hungary	BUX	Portugal	PSI 20
Cyprus	CSE	Ireland	ISEQ 20	Romania	BET
	General				
Czech Republic	PX	Italy	FTSE MIB	Slovakia	SAX
Denmark	OMXC 25	Latvia	OMX Riga	Slovenia	SBITOP
Estonia	OMX Tallinn	Lithuania	OMX Vilnius	Spain	IBEX 35
Finland	OMXH 25	Luxembourg	LuxX	Sweden	OMXS 30

Source: Refinitiv Eikon database.

The countries are grouped into three categories: EU-27 (all EU member countries), Eurozone (countries that have adopted the euro), and Non-Eurozone (emerging economies within the EU that have not adopted the euro, excluding Denmark and Sweden). This categorization allows for a detailed examination of financial integration across different levels of economic development and currency regimes within the EU. The primary focus is on understanding the financial integration patterns during significant economic periods, namely the Global Financial Crisis (December 1, 2007 - December 31, 2008), the European Sovereign Debt Crisis (December 1, 2009 - December 31, 2011),

and the COVID-19 Crisis (January 1, 2020 - December 31, 2021). Moreover, we divide the data sample into six sub-periods.

The Financial Integration Index is calculated for each of the three groups over the specified periods. The descriptive statistics of the data include minimum, maximum, and average values for the Financial Integration Index (based on daily return and daily volatility).

4. Results and discussions

4.1 *The analysis of the Financial Integration Index, computed by employing PCA on daily stock market index returns*

Figure 1 presents the dynamics of the Financial Integration Index (FII), computed by employing PCA on daily stock market index returns, for three country groups: EU27, Eurozone (EU20), and Non-Eurozone. The crisis periods are shaded and include the Global Financial Crisis (2007-2008), the European Sovereign Debt Crisis (2009-2011), and the COVID-19 Crisis (2020-2021).

Fig. 1. The dynamics of Financial Integration Index, computed by employing PCA on daily stock market index returns



Source: Authors' calculations.

Before the crisis period (2006-2007), FII gradually increased for all three groups, indicating a rise in the interdependence and synchronization of financial markets during the economic expansion before the Global Financial Crisis. The Eurozone (EU20) and Non-Eurozone exhibit higher levels of integration compared to EU27, suggesting stronger integration within the Eurozone and Central and Eastern Europe group of countries.

During the Global Financial Crisis (December 1, 2007 - December 31, 2008), FII increased sharply across all three groups at the onset of the crisis, reflecting a surge in their interdependence. The rise is more pronounced in the Non-Eurozone, indicating a greater vulnerability of emerging financial markets to external shocks. Toward the end of the crisis period, the index tends to slowly decrease, suggesting a partial recovery as markets stabilize.

During the European Sovereign Debt Crisis (December 1, 2009 - December 31, 2011), all three groups showed a gradual increase in FII, followed by a declining trend across all three groups, especially in the Eurozone and Non-Eurozone. This suggests a fragmentation of financial markets within the Eurozone, driven by sovereign debt issues and economic uncertainty. The Non-Eurozone continues to show high values of the

Financial Integration Index, reflecting the vulnerability of emerging financial markets to economic shocks within the Eurozone.

The period following the European Sovereign Debt Crisis (2012-2019) is characterized by a gradual and stable decrease in FII across all three groups. The levels of financial integration remain higher in the Non-Eurozone and the Eurozone compared to EU27, suggesting a consolidation of financial market interdependence within the two groups.

During the COVID-19 Crisis (January 1, 2020 - December 31, 2021), FII climbed sharply at the start of the crisis, reflecting increased uncertainty. After the initial escalation, in the end of the crisis, all three groups showed significant drops in FII, indicating rapid adaptation of financial markets to new economic conditions and the economic support measures implemented globally. The Non-Eurozone and the Eurozone continue to exhibit a higher level of financial integration compared to EU27.

The Non-Eurozone and the Eurozone consistently show higher levels of financial integration compared to EU27, indicating stronger interdependence and better synchronization of financial markets within the two groups. The Non-Eurozone displays the highest volatility in FII, indicating the vulnerability of emerging financial markets to external shocks. All three groups show a capacity for recovery after crisis periods. This analysis suggests that financial markets in the Non-Eurozone and the Eurozone are better integrated compared to the markets in EU27. Moreover, FII dynamics are heavily influenced by the crisis periods in all three groups.

Table 2 illustrates the minimum, maximum, and average values of FII for three groups of countries: EU-27, Eurozone (EU-20), and Non-Eurozone.

Table 2. Financial Integration Index statistics

Region	EU-27	EU-20	Non-Eurozone
Min	0.34	0.37	0.39
Max	0.58	0.59	0.66
Average	0.47	0.49	0.53

Source: Authors' calculations.

For the EU-27, FII shows a minimum value of 0.34, a maximum value of 0.58, and an average value of 0.47. These figures indicate that the financial integration within the entire European Union varies significantly, with periods of both low and high integration. The relatively wide range between the minimum and maximum values suggests that the integration level of financial markets in the EU-27 has experienced considerable fluctuations over the analyzed period.

In the Eurozone (EU-20), FII ranges from a minimum of 0.37 to a maximum of 0.59, with an average value of 0.49. This group displays slightly higher values across all metrics compared to the EU-27, reflecting a generally higher level of financial integration. The closer proximity of the minimum and maximum values to each other, relative to the EU-27, indicates more stability in the Financial Integration Index of Eurozone countries. The higher average value suggests stronger and more consistent financial market interdependence within the Eurozone.

For the Non-Eurozone, FII ranges from a minimum of 0.39 to a maximum of 0.66, with an average value of 0.53. This group exhibits the highest maximum value, indicating

periods of very high financial integration. However, the wide range between the minimum and maximum values points to significant volatility and fluctuations in the financial integration of these emerging markets. The average value of 0.53, the highest among the three groups, suggests that, on average, Non-Eurozone countries have a relatively high level of financial integration, albeit with greater instability.

The Eurozone (EU-20) demonstrates a more stable and moderately high level of financial integration compared to the EU-27, which shows greater fluctuations. The Non-Eurozone has the highest average and maximum values, indicating strong financial integration during certain periods but also the highest volatility.

Table 3 presents the average values of FII for the EU-27, Eurozone (EU-20), and Non-Eurozone across various time intervals from 2006 to 2024. The overall average of FII from 2006 to 2024 is 0.47 for the EU-27, 0.49 for the Eurozone, and 0.53 for the Non-Eurozone. This indicates that, over the long term, the Non-Eurozone countries have the highest average level of financial integration, followed by the Eurozone and the EU-27.

Table 3. Average Financial Integration Index by time period for EU27, Eurozone (EU20), and Non-Eurozone (2006-2024)

Return	EU-27	EU-20	Non-Eurozone
Average (2006-2024)	0.47	0.49	0.53
Average (2006-2007)	0.47	0.44	0.47
Average (2008-2014)	0.49	0.50	0.56
Average (2015-2019)	0.42	0.44	0.46
Average (2020-2021)	0.56	0.57	0.62
Average (2022-2024)	0.47	0.50	0.53

Source: Authors' calculations.

During the pre-crisis period (2006-2007), FII averages 0.47 for the EU-27, 0.44 for the Eurozone, and 0.47 for the Non-Eurozone. The relatively lower value for the Eurozone suggests that financial integration was still developing and was somewhat lower compared to the broader EU-27 and Non-Eurozone groups. The period encompassing the Global Financial Crisis and the European Sovereign Debt Crisis (2008-2014) shows increased average values: 0.49 for the EU-27, 0.50 for the Eurozone, and 0.56 for the Non-Eurozone. The rise in these values reflects a stronger financial market interdependence within the Eurozone, during crises episodes, for all groups, with the Non-Eurozone showing the most significant increase, indicating stronger integration efforts or higher sensitivity to global financial trends.

From 2015 to 2019, the averages decreased to 0.42 for the EU-27, 0.44 for the Eurozone, and 0.46 for the Non-Eurozone. This decline suggests a period of reduced financial integration or stabilization at lower levels following the post-crisis adjustments. During the COVID-19 crisis (2020-2021), FII averages peak again at 0.56 for the EU-27, 0.57 for the Eurozone, and 0.62 for the Non-Eurozone. The significant increase across all groups reflects heightened financial integration as markets responded to the global economic disruptions caused by the pandemic.

In the most recent period (2022-2024), the averages are 0.47 for the EU-27, 0.50 for the Eurozone, and 0.53 for the Non-Eurozone. These values suggest a return to the long-term average levels observed over the entire period, indicating a stabilization of

financial integration post-COVID-19 crisis, with the Non-Eurozone maintaining its relatively higher level of integration.

The Financial Integration Index data reveals how financial integration fluctuates in response to economic crises, regulatory changes, and global economic conditions, with notable increases during crisis episodes, and stabilizing trends in post-crisis environments. Over the long term, the Non-Eurozone countries consistently show higher average financial integration levels compared to the EU-27 and Eurozone. This may be due to their emerging market status, which often entails greater sensitivity to global financial conditions and stronger integration efforts to attract investment and foster economic growth.

4.2 The analysis of the Financial Integration Index, computed by employing PCA on daily stock market index volatility

Figure 2 illustrates the dynamics of the Financial Integration Index, computed by employing PCA on daily stock market index volatility, for the EU27, Eurozone (EU20), and Non-Eurozone groups of countries. The shaded areas indicate the crisis periods: the Global Financial Crisis (December 1, 2007 - December 31, 2008), the Sovereign Debt Crisis (December 1, 2009 - December 31, 2011), and the COVID-19 Crisis (January 1, 2020 - December 31, 2021).

Fig. 2. The dynamics of Financial Integration Index, computed by employing PCA on daily stock market index volatility



Source: Authors' calculations.

In the period before the crisis (2006-2007), the Financial Integration Index was relatively low and stable across all three groups. The Non-Eurozone group shows slightly higher volatility compared to the EU27 and Eurozone, indicating that emerging markets present higher degrees of heterogeneity. During the Global Financial Crisis, the Financial Integration Index spiked sharply for all three groups. The increase is most pronounced in the Non-Eurozone, where FII reaches its highest levels. This reflects the severe impact of the financial crisis on global markets, with emerging markets experiencing greater synchronicity. The EU27 and Eurozone also see significant increases in FII, indicating widespread market turbulence and uncertainty during this period.

Following the Global Financial Crisis, FII decreases gradually across all groups, reaching lower levels by 2010. The decline is more marked in the EU27 and Eurozone, suggesting that these regions were able to stabilize more quickly compared to the Non-

Eurozone. During the European Sovereign Debt Crisis, FII increased again, particularly in the Eurozone and Non-Eurozone groups. Both regions show elevated volatility, reflecting the interconnectedness of financial markets and the spillover effects of the crisis. The EU27 shows a moderate increase in FII, indicating that the crisis had a widespread but varied impact across Europe.

From 2012 to 2019, FII levels stabilize and remain relatively low for all groups, though the Non-Eurozone consistently exhibits higher levels of integration compared to the EU27 and Eurozone. This period of stability suggests that the financial markets recovered from the previous crises. The onset of the COVID-19 pandemic in early 2020 leads to a sharp and significant increase in FII across all three groups. The Non-Eurozone again experiences the highest FII levels, followed by the EU27 and the Eurozone. This reflects the unprecedented economic disruptions caused by the pandemic, with financial markets reacting to the uncertainty and rapidly changing economic conditions.

In the most recent period (2022-2024), FII levels decreased from their pandemic highs but remained somewhat elevated, particularly in the Non-Eurozone. This suggests ongoing market adjustments and the lingering effects of the pandemic on global economic stability. The EU27 and Eurozone show lower FII compared to the Non-Eurozone, indicating a relative stabilization but still reflecting the aftermath of the COVID-19 disruptions.

The trends observed in the figure can be attributed to several key factors. During the crisis episodes, financial markets experienced severe disruptions, leading to sharp increases in co-movements, in the presence of the herding effect, as investors reacted to uncertainties and market turbulences. The Non-Eurozone countries were particularly sensitive to these global shocks. In the post-crisis periods, the Non-Eurozone remained more volatile due to its inherent market characteristics.

Table 4 provides the minimum, maximum, and average values of FII for three groups of countries: EU-27, Eurozone (EU-20), and Non-Eurozone.

Table 4. Financial Integration Index statistics

Region	EU-27	EU-20	Non-Eurozone
Min	0.26	0.30	0.30
Max	0.72	0.72	0.78
Average	0.47	0.47	0.57

Source: Authors' calculations.

For the EU-27, volatility ranges from a minimum value of 0.26 to a maximum value of 0.72, with an average value of 0.47. These values indicate that the financial markets in the EU-27 exhibit considerable fluctuations. The average value of 0.47 suggests that, on the whole, integration in the EU-27 is moderate.

In the Eurozone (EU-20), volatility has a minimum value of 0.30, a maximum value of 0.72, and an average value of 0.47. Similar to the EU-27, FII levels in the Eurozone show significant fluctuations, with both low and high periods. The identical average values for the EU-27 and Eurozone indicate that, overall, the integration levels are comparable between these two groups.

The Non-Eurozone countries exhibit a minimum volatility value of 0.30, a maximum value of 0.78, and an average value of 0.57. The higher maximum value of 0.78 and the

highest average value of 0.57 suggest that the Non-Eurozone countries experience greater integration compared to the EU-27 and Eurozone. Moreover, this implies that financial markets in the Non-Eurozone are more prone to fluctuations and instability and respond similarly to economic events.

Table 5 presents the average values of FII for the EU-27, Eurozone (EU-20), and Non-Eurozone across various time intervals from 2006 to 2024.

Table 5. Average Financial Integration Index by time period for EU27, Eurozone (EU20), and Non-Eurozone (2006-2024)

Volatility	EU-27	EU-20	Non-Eurozone
Average (2006-2024)	0.47	0.47	0.57
Average (2006-2007)	0.35	0.37	0.47
Average (2008-2014)	0.45	0.46	0.55
Average (2015-2019)	0.42	0.42	0.52
Average (2020-2021)	0.66	0.64	0.71
Average (2022-2024)	0.53	0.54	0.63

Source: Authors' calculations.

For the overall period from 2006 to 2024, the average volatility is 0.47 for both the EU-27 and Eurozone and 0.57 for the Non-Eurozone. This indicates that over the long term, the Non-Eurozone countries experience higher interconnectedness compared to the EU-27 and Eurozone, reflecting greater market sensitivity to external shocks in the emerging markets.

During the pre-crisis period (2006-2007), the average volatility was 0.35 for the EU-27, 0.37 for the Eurozone, and 0.47 for the Non-Eurozone. The lower FII levels in the EU-27 and Eurozone suggest a period of relative market stability before the onset of the Global Financial Crisis. The higher FII levels in the Non-Eurozone indicate that these markets were already experiencing greater synchronicity, even before the crisis, likely due to their developing nature and higher sensitivity to global economic conditions.

The period encompassing the Global Financial Crisis and the Sovereign Debt Crisis (2008-2014) shows increased average FII values: 0.45 for the EU-27, 0.46 for the Eurozone, and 0.55 for the Non-Eurozone. The rise in FII across all groups reflects the significant market turbulence and uncertainty during these crises. The Non-Eurozone exhibits the highest increase, indicating that these markets were more affected by global economic instability and experienced greater fluctuations.

From 2015 to 2019, the average volatility slightly decreased to 0.42 for both the EU-27 and Eurozone and to 0.52 for the Non-Eurozone. This period marks a phase of post-crisis stabilization, with markets gradually recovering and volatility reducing.

The COVID-19 crisis period (2020-2021) sees a big jump in average FII to 0.66 for the EU-27, 0.64 for the Eurozone, and 0.71 for the Non-Eurozone. The significant rise in FII across all groups highlights the unprecedented economic disruptions caused by the pandemic. The highest FII is observed in the Non-Eurozone, reflecting the extreme sensitivity of these markets in response to global economic shocks and uncertainties.

In the most recent period (2022-2024), the average volatility decreased to 0.53 for the EU-27, 0.54 for the Eurozone, and 0.63 for the Non-Eurozone. This decline suggests a period of recovery and stabilization following the peak of the COVID-19 crisis.

The observed FII values reflect the varying levels of financial stability and sensitivity to external shocks in different regions. During stable economic periods, FII is relatively low for the EU-27 and Eurozone. In contrast, the Non-Eurozone shows higher levels of FII, even during stable periods. During turbulent periods, FII spikes significantly across all regions due to severe market disruptions and heightened uncertainty. The Non-Eurozone, being more vulnerable to these shocks, experiences the highest FII levels.

4.3 Daily return versus daily volatility as measures of the degree of integration

Figures 3-5 show a comparative analysis of the Financial Integration Index, computed by employing PCA on daily stock market index returns and daily stock market index volatilities, for the EU27, Eurozone (EU20), and Non-Eurozone groups of countries. The crisis periods—the Global Financial Crisis (GFC), the European Sovereign Debt Crisis, and the COVID-19 pandemic—are shaded to highlight their impact on FII.

Fig. 3. Comparative analysis of Financial Integration Index for EU27 (2006-2024)



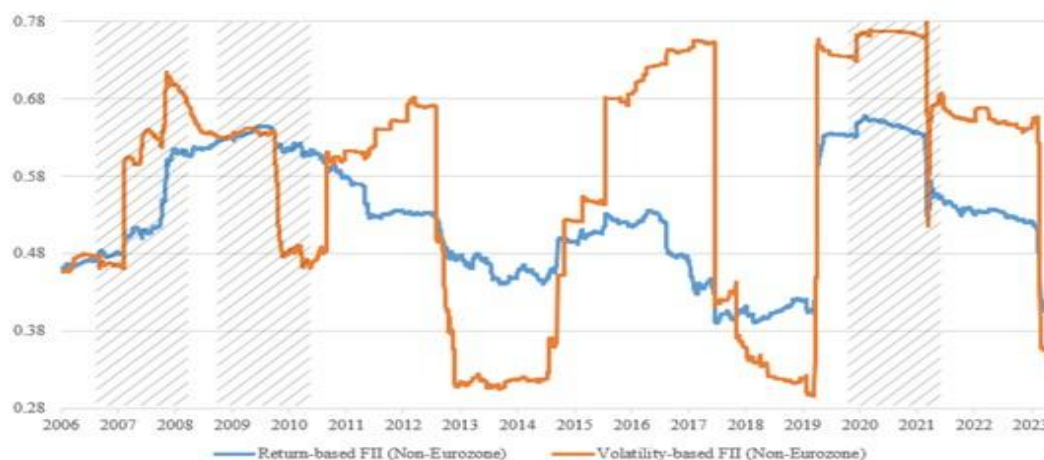
Source: Authors' calculations.

Fig. 4. Comparative analysis of Financial Integration Index for EU20 (2006-2024)



Source: Authors' calculations.

Fig. 5. Comparative analysis of Financial Integration Index for Non-Eurozone (2006-2024)



Source: Authors' calculations.

The comparative analysis reveals distinct patterns in the behavior of FII derived from returns and volatility. During major crises, FII based on volatility shows more pronounced spikes compared to FII based on returns. This is indicative of the heightened sensitivity of volatility to market turmoil, as volatility tends to increase sharply in response to market stress and uncertainty. In contrast, FII based on returns exhibits a more stable trend, with gradual increases and decreases that align with broader economic cycles.

In order to enhance our analysis, we set up tables 6-8, which report a comparative analysis of the minimum, maximum, and average values of FII, computed by employing PCA on daily stock market index returns and daily stock market index volatilities, for the EU27, Eurozone (EU20), and Non-Eurozone groups of countries.

Table 6. Summary statistics of Financial Integration Index for EU-27 (2006-2024)

EU-27	Return-based FII	Volatility-based FII
Min	0.34	0.26
Max	0.58	0.72
Average	0.47	0.47

Source: Authors' calculations.

Table 7. Summary statistics of Financial Integration Index for EU-20 (2006-2024)

EU-20	Return-based FII	Volatility-based FII
Min	0.37	0.30
Max	0.59	0.72
Average	0.49	0.47

Source: Authors' calculations.

Table 8. Summary statistics of Financial Integration Index for Non-Eurozone (2006-2024)

Non-Eurozone	Return-based FII	Volatility-based FII
Min	0.39	0.30
Max	0.66	0.78
Average	0.53	0.57

Source: Authors' calculations.

Our results reveal that, for all country groups, the minimum values of FII extracted from volatility are lower than the minimum values of FII obtained from volatility, while the

maximum values of FII extracted from volatility are higher than the maximum values of FII obtained from volatility.

In our opinion, stock market index volatility is a more sensitive and, therefore, a better measure for assessing the degree of integration, compared to stock market index returns. The higher sensitivity of volatility to market conditions underscores its utility in real-time monitoring of financial integration. Volatility captures the rapid fluctuations in investor sentiment and market conditions that are often associated with crises, providing a more immediate and dynamic picture of financial integration. This makes it particularly useful for policymakers and investors who need to respond swiftly to changing market conditions.

5. Conclusions

This paper has undertaken a comprehensive analysis of the financial integration within European Union (EU) financial markets, utilizing a dynamic Principal Component Analysis (PCA) approach to compute the Financial Integration Index (FII) from both daily stock market index returns and volatilities. Our analysis spans over two decades (January 2005 – April 2024) and focuses on three distinct groups of countries within the EU: the EU-27, the Eurozone, and the Non-Eurozone emerging economies.

Our analysis reveals several interesting findings. Firstly, our results indicate a significant evolution of financial integration across the EU financial markets. Integration has generally increased over time, with notable fluctuations during major crises such as the Global Financial Crisis (GFC), the European Sovereign Debt Crisis, and the COVID-19 pandemic. The Eurozone and Non-Eurozone groups exhibited higher levels of financial integration compared to the broader EU-27, reflecting stronger interdependencies within these more specific groupings.

Secondly, the study highlights that stock market index volatility is a more sensitive measure of financial integration compared to stock market index returns. During periods of economic turmoil, volatility-based FII spikes more sharply, capturing the immediate impact of market shocks. This sensitivity makes volatility a more effective tool for real-time monitoring of financial integration and market conditions.

Finally, the analysis reveals that major economic disruptions significantly influence the dynamics of financial integration. Each crisis period studied led to increased financial integration as markets reacted to heightened uncertainty and volatility. The Non-Eurozone group displayed the highest volatility in FII, indicating greater sensitivity to external shocks, while the Eurozone showed more stability, reflecting its coordinated monetary policies and stronger economic cohesion.

Our findings have several important policy implications. The heightened sensitivity of volatility-based FII suggests that policymakers should monitor volatility closely as an early warning indicator of financial distress. Timely intervention can mitigate the adverse effects of market turbulence. Moreover, the persistent high volatility in Non-Eurozone countries underscores the need for targeted policies to improve regulatory frameworks and market infrastructure. Finally, the results emphasize the importance of considering both returns and volatility when assessing international portfolio diversification strategies.

Higher financial integration can lead to increased cross-market correlations, potentially reducing the benefits of diversification during crisis periods.

Despite the original findings of this study, several limitations should be acknowledged. Key among these are the data limitations, which might not capture all dimensions of financial integration. Additionally, the focus on EU countries, while insightful, limits the generalizability of the findings. Future research should explore these limitations by incorporating more diverse datasets and including comparative analyses with other regions. Additionally, investigating the role of technological advancements and regulatory changes in shaping financial integration could provide valuable insights for policymakers and investors.

6. References

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