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One index, many regions: revenue distribution and index performance

Evidence from the Euro Stoxx 50

School of Accounting and Finance

Master's thesis in Finance

Master's Degree Programme in Finance

Vaasa 2025

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Thesis title: One index, many regions: revenue distribution and index performance – Evidence from the Euro Stoxx 50
Degree: Master of Science in Economics and Business Administration
Supervisor: Klaus Grobys
Year of graduation: 2025 **Number of pages:** 81

ABSTRACT:
This thesis investigates an alternative perspective on the Euro Stoxx 50 index by incorporating the regional revenue exposure of its constituents when analyzing comovement with global and regional MSCI equity indexes. While previous academic research has typically evaluated index correlations based on the listing locations of their constituent companies, this approach overlooks the fact that many firms operate globally and derive significant revenues outside their home countries. The objective of this study is therefore to determine whether accounting for international revenues enhances the understanding of co-movement between indexes.

Focusing on the period from 2019 to 2024, the study deconstructs the Euro Stoxx 50 by allocating each constituent's revenue across five regions: Europe, the Middle East and Africa, Asia-Pacific, the Americas, and the rest of the world, with an additional residual category for undisclosed or other revenues. These regional revenue shares are then used to weight the returns of corresponding MSCI regional indexes, forming a revenue-weighted composite index referred to in this thesis as the models. This approach builds on existing literature suggesting that risk premiums for multinational corporations are more closely tied to the scope and scale of their global operations rather than their domestic performance alone.

The empirical results, based on regression analysis, demonstrate that the revenue-weighted model closely tracks the performance of the Euro Stoxx 50 and explains its return dynamics better than any single regional or global index, with the exception of the MSCI AC Europe and Middle East index. Notably, the model exhibits stronger correlation with other global and regional indexes and significantly aligns with the performance of the MSCI AC World Index. These findings indicate that incorporating firms' international revenue structures yields a more precise understanding of index behavior and offers valuable insights for both investors and index developers.

By expanding the conceptual framework of international portfolio analysis, this study offers a meaningful contribution to global finance, especially in the context of geopolitical and macroeconomic uncertainty. It lays the groundwork for future research on how multinational corporations and the indexes that represent them could alternatively be evaluated, weighted, and interpreted within global investment strategies.

Keywords: International portfolio, multinational corporations, MNC, regional revenue exposure

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Laskentatoimen ja rahoituksen yksikkö
Tekijä: Mark Mozheiko
Tutkielman nimi: One index, many regions: revenue distribution and index performance – Evidence from the Euro Stoxx 50
Tutkinto: Kauppatieteiden maisteri
Työn ohjaaja: Klaus Grobys
Valmistumisvuosi: 2025 **Sivumäärä:** 81

TIIVISTELMÄ:
Tämä tutkielma tarkastelee Euro Stoxx 50 -osakeindeksiä vaihtoehtoisesta näkökulmasta sisällyttämällä sen yritysten alueellisen liikevaihtojakauman osaksi analyysiä, kun arvioidaan yhteisliikettä globaalien ja alueellisten MSCI-osakeindeksien kanssa. Aiempi akateeminen tutkimus on tyypillisesti perustunut indeksien välisen korrelaation arviointiin yritysten listautumismaiden perusteella, mutta tämä lähestymistapa sivuuttaa sen, että monet yritykset toimivat globaalisti ja saavat merkittävän osan liikevaihdostaan kotimaidensa ulkopuolelta. Tutkielman tavoitteena on selvittää, parantaako kansainvälisen liikevaihdon huomioiminen ymmärrystä indeksien välisestä yhteisliikkeestä.

Tutkimus keskittyy vuosien 2019 ja 2024 väliseen ajanjaksoon ja purkaa Euro Stoxx 50 -indeksin viiteen alueeseen yritysten liikevaihdon jakautumisen mukaan: Eurooppa, Lähi-itä ja Afrikka, Aasia ja Tyynenmeren alue, Amerikka sekä muu maailma. Lisäksi mukana on erillinen luokka niille liikevaihdoille, joita ei ole eritelty tai jotka eivät sovi muihin kategorioihin. Näitä alueellisia liikevaihto-osuuksia käytetään painoina vastaavien MSCI-alueindeksien tuotoissa, ja niiden perusteella muodostetaan liikevaihtopainotettu yhdistelmäindeksi, jota tässä tutkielmassa kutsutaan malliksi. Lähestymistapa pohjautuu aiempaan kirjallisuuteen, jonka mukaan monikansallisten yritysten riskipreemiot ovat tiiviimmin sidoksissa niiden toiminnan laajuuteen ja suhteelliseen merkittävyyteen globaalisti, ennemmin kuin pelkästään kotimaan rekisteröinnin tai listautumisen perusteella.

Analyysimenetelmänä käytetään regressioanalyysia, joka osoittaa liikevaihtopainotetun mallin seuraavan tarkasti Euro Stoxx 50 -indeksin kehitystä ja selittää sen tuottoja paremmin kuin mikään yksittäinen alueellinen tai globaali indeksi, pois lukien MSCI AC Eurooppa ja Lähi-itä -indeksi. Malli korreloi merkittävästi myös muiden globaali- ja alueindeksien kanssa ja on erityisen linjassa MSCI AC World -indeksin kehityksen kanssa. Tulokset viittaavat siihen, että yritysten kansainvälisen liikevaihtorakenteen huomioon ottaminen tuottaa tarkemman käsityksen indeksin käyttäytymisestä ja tarjoaa arvokkaita näkemyksiä niin sijoittajille kuin indeksien kehittäjille.

Laajentamalla kansainvälisen portfolioteorian käsitteellistä viitekehystä tämä tutkimus tarjoaa merkittävän panoksen globaaliin rahoitukseen, erityisesti geopoliittisen ja makrotaloudellisen epävarmuuden aikana. Se luo perustan jatkotutkimukselle siitä, miten monikansallisia yrityksiä ja niitä edustavia indeksejä voidaan vaihtoehtoisesti arvioida, painottaa ja tulkita osana globaaleja sijoitusstrategioita.

Avainsanat: Kansainvälinen portfolio, monikansalliset yhtiöt, MNC, alueellinen liikevaihtorakenne

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Abbreviations

AC All Countries. Commonly used in financial indexes, such as MSCI AC APAC, to indicate inclusion of both developed and emerging markets within the Asia-Pacific region.

APAC Asia-Pacific region.

CAPM Capital asset pricing model is a theoretical framework used to calculate the expected rate of return.

EMEA Region that includes Europe, the Middle East, and Africa.

GPR Geopolitical risk index, measures geopolitical uncertainty using data from major newspaper coverage.

HGM High global market diversifiers; firms generating over 70% of their revenue from foreign markets.

ICB Industry Classification Benchmark, a taxonomy for categorizing companies by sectors and industries.

LGM Low global market diversifiers; firms generating less than 50% of their revenue from foreign markets.

MGM Medium global market diversifiers; firms generating 50-70% of their revenue from foreign markets.

MNC Multinational corporations that operate and earn revenue across multiple countries

SX5E Euro Stoxx 50 index.

WI World index, representing the majority of the global investable equity universe.

1 Introduction

In an increasingly globalized financial environment, equity indexes such as the Euro Stoxx 50 are frequently used as benchmarks, particularly through exchange-traded funds (ETFs). However, the constituents on which these indexes are built are often multinational corporations (MNCs) that derive a significant portion of their revenues from foreign markets, rather than the countries where they are listed or registered. This can result in regional ETFs being potentially misleading, as their performance may not accurately reflect domestic market conditions but instead may depend significantly on foreign market dynamics.

Also, from a risk management perspective, it is crucial for investors to monitor how cash flows or revenues are distributed across their investment portfolios, as certain regions may underperform relative to others. This is particularly important for ensuring effective diversification during periods of market uncertainty. A revenue shock in one region can significantly impact the overall performance of even a domestically focused portfolio if revenue distributions are not properly analyzed.

Existing literature has largely overlooked the analysis of index performance relative to regional revenue proportions, focusing instead on comparisons based on the geographic locations where constituent companies are listed. This paper aims to enhance understanding in the field by introducing an additional dimension and further extending the findings of Diermeier and Solnik (2001) and Dumas, Gabuniya, and Marston (2022), who argue that accounting for regional cash flows or revenues provides a more accurate reflection of the risk exposures tied to equity returns, irrespective of a company's listing location.

1.1 Purpose of the study

Investors often benefit from diversifying their portfolios across various geographical markets to mitigate the risks associated with concentrating investments in a single region (Levy & Sarnat, 1970). However, this assumption does not always hold when investing in multinational corporations, which may derive only a minority of their cash flows from their domestic markets (Dumas, Gabuniya, & Marston, 2023). Consequently, a more effective indicator is needed for portfolio management, one that can track the global distribution of investments regardless of where the equities are issued. Such an indicator is essential for understanding a portfolio's revenue dependency on different regions and how these proportions evolve over time. This issue is particularly relevant for equity indexes and ETFs, where constituent firms often exhibit substantial international revenue footprints. For example, only 42.3% of the Euro Stoxx 50 constituents' revenues between 2019 and 2023 were derived from Europe.

For example, domestic companies in Germany experienced a dramatic decline in their share of the total number of firms selling in Germany, with their proportion dropping from 60.5% to 24.6% between 2000 and 2014 (Dumas et al., 2023). A similar, though less pronounced, trend was observed in France during the same period (Dumas et al., 2023). This shift reflects the growing internationalization of large European companies, underscoring the need to look beyond a company's country of listing when assessing its geographical risk and economic exposure. As a result, the traditional approach of selecting stocks based on listing location and operating sector as a tool for portfolio risk management appears increasingly inadequate (Diermeier & Solnik, 2001). Instead, investment strategies should incorporate the geographic diversity of international companies' cash flows or revenues as proxy in order to capture actual economic exposure more accurately.

In theory, cash flows or revenues from different regions may warrant distinct risk premiums due to variations in geopolitical stability, inflation and exchange rate volatility,

market maturity, and economic growth. This suggests that the international capital asset pricing model (CAPM) should account for these region-specific risk factors (Dumas & Solnik, 1995). Challenging this assumption, investors may assign a premium to certain revenue sources due to home bias or other behavioral pricing considerations, leading to higher valuations for firms with a domestic focus (French & Poterba, 1991). As French and Poterba (1991) argues, institutional factors such as investor protection and legal frameworks, along with risks related to currency and political instability, increase investor uncertainty regarding foreign markets. This heightened uncertainty may reduce their willingness to invest in foreign firms, thereby contributing to a premium for domestically headquartered companies.

This paper investigates the extent to which the performance of the Euro Stoxx 50 equity index can be explained by the regional revenue exposures of its constituent companies and the performance of the corresponding regional equity markets over time. The primary aim is to provide clearer insights into the relationship between regional revenue dependency and the behavior of European equities.

In this study, the Euro Stoxx 50 equity index is deconstructed into the following regions based on constituent revenues: Asia-Pacific (APAC), Europe, the Middle East and Africa (EMEA), the Americas, and the rest of the world. Due to the absence of a standardized framework for reporting geographical revenue exposure, analyzing data at the country level presents notable challenges and limitations. While some companies report revenues at the continental level, others provide more granular, country-specific details. In some cases, multinational corporations MNCs report part of their regional revenues as “other revenues”, under “hedging”, or as subsidiary revenues, which does not clarify the regional allocation of these amounts. Consequently, such revenues are assigned to a fifth group, labeled “other”. Ideally, a comprehensive understanding of cash flow generation across regions would offer the most effective means of analyzing a company’s operational dependencies (Dumas et al., 2022). In the absence of detailed regional cash flow data, using revenue exposure as a proxy represents a practical compromise. Regional revenue splits may warrant further study, particularly as improved geographic transparency has

been shown to attract greater foreign investment (Gelos & Wei, 2005).

1.2 Research problem and hypothesis development

Although prior research recognizes the increasing globalization of corporate revenues, a notable gap persists in the literature concerning the influence of geographical revenue exposure on equity pricing at the index level. This study addresses that gap by providing empirical evidence on the extent to which foreign revenue contributions influence the performance of the Euro Stoxx 50, one of Europe's most closely followed stock indexes. The analysis offers a quantitative assessment of the extent to which variations in regional revenue exposure are reflected in equity valuations, thereby enhancing the understanding of international revenue dependencies within European stock markets.

More specifically, the research question addressed in this paper is as follows:

> *To what extent does the geographic revenue exposure of Euro Stoxx 50 constituents explain the performance of the index, compared to traditional market-cap based regional indexes?*

To address this research question, we utilize four regional equity indexes: MSCI All Country (AC) APAC, MSCI AC Europe and Middle East (serving as a proxy for EMEA), MSCI AC America, and the MSCI AC World Index, which collectively represent their respective regions from both precise and broad economic development perspectives. The performance of these indexes is aggregated over time using the Euro Stoxx 50's geographical revenue distribution as weighting factors. This revenue-weighted composite performance is then compared to the actual performance of the Euro Stoxx 50, enabling a direct assessment of the relationship between regional revenue exposure and index performance, and facilitating the testing of the underlying hypothesis.

Essentially, if investors exhibit a preference for a specific region, they are likely to assign greater value to revenue generated within that region Pirinsky and Wang (2006). This

idea is supported by Froot and Dabora (1999), who argue that the location of trade influences stock prices due to factors such as tax-induced investor heterogeneity, institutional inefficiencies, and market-wide noise driven by irrational investor behavior. Furthermore, Ivković and Weisbenner (2005); Mavruk (2011) provide evidence for the familiarity hypothesis, which posits that domestic investors tend to prefer domestic stocks even when these do not generate abnormal returns. Building on this, the present study aims to explore whether firms' revenues are more highly valued when they are derived from domestic markets, as opposed to regions where the stock is traded. Therefore, this research tests the following hypothesis to address the research question:

H1: A composite index constructed from regional MSCI indexes, weighted by the Euro Stoxx 50 constituents' revenue distribution, will closely track the performance of the Euro Stoxx 50.

H2: The revenue-weighted composite model will track the Euro Stoxx 50 more accurately than any single MSCI index.

H3: Incorporating firms' regional revenue breakdowns will result in a composite index whose returns exhibit stronger correlations with regional MSCI indexes than the original Euro Stoxx 50 index.

1.3 Intended contribution

The regional revenue distribution of MNCs has been relatively underexplored in academic research. Existing studies tend to emphasize correlations between national equity indexes, often without a detailed investigation into the geographical origins of the revenues underpinning these indexes. This paper, therefore, aims to advance understanding of the degree to which regional equity indexes reflect the actual revenue composition of MNCs.

Building on the insight of Heston and Rouwenhorst (1994) that country-specific factors

drive equity returns, and on more recent developments by Diermeier and Solnik (2001) and Dumas et al. (2023), which incorporate firms' foreign sales into performance analysis, this thesis extends the framework to a market-cap-weighted European index. In particular, the recent studies by Dumas et al. (2022) and Dumas et al. (2023) are highly relevant; one of their key findings is that expected-maximization (EM) indexes capture geographical risks more effectively than traditional national indexes. This study advances that work by employing actual index weights, rather than relying on equal-weighted approximations, thereby offering a more realistic and practical perspective on regional exposure and its influence on index performance.

Ultimately, this paper contributes to the literature on international finance, portfolio theory, and asset pricing. By engaging with a relatively underexamined dimension of global markets, it provides a foundation for future research in international portfolio management, with particular attention to firms' geographical revenue exposure and the resulting market dynamics. More specifically, the study offers insights into equity portfolio construction and risk evaluation in the context of geopolitical instability and macroeconomic disruptions.

1.4 Structure of the study

This research paper begins with a review of the literature in chapter 2, which covers key concepts and prior studies on geographic revenue exposure, along with a brief overview of findings related to international risk premiums. Chapter 3 provides a foundational overview of the construction and updating processes of the Euro Stoxx 50 and the MSCI AC APAC, EMEA, and America indexes. Chapter 4 outlines the methodology used for deconstructing the equity index and details the clustering approach employed for hypothesis testing. Chapter 5 presents the empirical results and discusses the study's limitations. Finally, chapter 6 concludes the paper by summarizing its key findings and contributions.

2 Literature review

The purpose of this chapter is twofold: first, to evaluate prior research that shares conceptual similarities with this study, and second, to synthesize theoretical insights from the existing literature in order to develop a framework grounded in established findings. Much of the earlier research on trade location and revenue exposure adopts a predominantly macroeconomic perspective, focusing on how international revenue streams influence domestic stock market behavior. In contrast, this paper takes a more focused approach by using the Euro Stoxx 50 as a case study to examine in greater depth how international revenues affect the performance of European equities.

2.1 Multinational corporations' revenue exposures and stock returns

The findings of Heston and Rouwenhorst (1994) suggest that investing in the same industry across different countries yields superior diversification benefits compared to investing across industries within a single country. However, this insight becomes more complex when considering multinational corporations that derive revenues from multiple countries while operating within a single industry. In such cases, factors like the comovement of stock returns between host and domestic countries, as well as country-specific risks, significantly influence risk-adjusted returns (Fillat, Garetto, & Oldenski, 2015).

In their analysis, Heston and Rouwenhorst (1994) employed a factor model that separately identified country and industry effects using binary (dummy) variables, assigning a value of 1 to indicate inclusion in a given country or industry and 0 otherwise. This allowed them to isolate and compare the performance and variance contributions of country and industry factors. The model they used is represented by equation 1, which disentangles these components to assess their individual impact on returns (Heston & Rouwenhorst, 1994):

$$R_{it} = \alpha_t + \sum_{j=1}^{7} \beta_{jt} I_{it} + \sum_{k=1}^{12} \gamma_{kt} C_{kt} + e_{it}, \tag{1}$$

Where α_t is the baseline return in period t, β represents the industry-specific effects, and γ captures the country-specific influences. The dummy variables I_{it} and C_{kt} indicate whether a firm belongs to a particular industry or country respectively. The term e_{it} denotes the firm-specific disturbance. The upper limits of the summations correspond to the number of industries (7) and countries (12) included in the analysis.

Another important study highlights a strong relationship between the returns of multinational corporations and foreign market factors, shaped by the extent of their international operations as measured by the proportion of foreign sales to total sales (Diermeier & Solnik, 2001). The authors found that incorporating foreign sales significantly alters the risk exposure profile of stocks, suggesting that a company's returns are more strongly influenced by where it generates revenue than by its country of listing.

In their methodology, the researchers created a domestic index by disaggregating the national index and adjusting it based on the proportion of revenue derived from the home country. This approach provided a more accurate representation of how stock returns behave in relation to domestic market conditions. Importantly, although individual firms may earn revenue from multiple countries, only the portion attributable to the domestic country was included in constructing the domestic index, and only if it exceeded a specified threshold (Adler & Solnik, 1974; Diermeier & Solnik, 2001).

Finally, Diermeier and Solnik (2001) extended the original model presented in equation 1 by incorporating MNCs' proportional sales by region, thereby recognizing revenue-based exposures in the return-generating process:

$$R_i = \alpha_i + \beta_i I_{dom} + \sum_{reg} \gamma_{i,reg} I_{reg} + \sum_{reg} \delta_{i,reg} C_{reg} + e_i \tag{2}$$

In this equation β, γ, and δ represent the exposures assigned to each factor, while I_{dom}, I_{reg} and C_{reg} correspond to the returns on the domestic index, the returns from regions (North America, Europe or Asia), and the currency returns of these regions measured in domestic currency respectively.

Finally, these two papers laid the foundation for the most recent studies on this subject. In particular, Dumas et al. (2022) expanded the domestic index using the expectation-maximization (EM) method, resulting in the so-called EM index. This index includes only the revenues generated within the respective country or zone by fully domestic companies, proportional revenues from multinational corporations originating from that country, and even expected negative weights due to unrelated returns, as determined by their model.

For illustrative purposes, consider a company domiciled in Germany that generates 70 percent of its revenue from France and the remaining 30 percent from Germany. According to the index construction methodology, the firm's representation is allocated proportionally across countries based on the geographical distribution of its revenues. Consequently, when constructing country-specific indexes for Germany and France, the company contributes 30 percent of its weight to the German index and 70 percent to the French index.

The underlying assumption remains unchanged: the proportion of sales generated abroad should correspond to the regions where the revenue is recognized, rather than to the location of the company's headquarters (Diermeier & Solnik, 2001; Dumas et al., 2022, 2023). Following a similar approach, this study examines the extent to which foreign revenue shares are reflected in the pricing of euro area firms. This research adopts assumptions consistent with those in Dumas et al. (2023), wherein stock returns are viewed as proxies for a company's exposure to risks in the regions where its revenues are generated, rather than in its country of domicile. In that study, the authors compared the performance of three types of indexes: the EM index, the national index (based on ISIN codes), and the domestic index, which includes only companies that derive at least 70 percent of their revenue from the host country. Their results indicate that EM indexes provide a more accurate representation of geographical risk exposure than national indexes and offer improved explanatory power for stock return behavior. These findings align with those of Fillat and Garetto (2015), who demonstrate that greater international revenue exposure alters firms' risk profiles, causing stock returns to align more closely

with both foreign and domestic market conditions.

2.2 International diversification and market integration

There is a substantial body of research on portfolio diversification. Modern portfolio theory posits that the variance of a portfolio can be calculated for two or more assets when the standard deviation and weight of each asset, along with the correlation coefficient between the assets, are known (Markowitz, 1952). Both industry and geographical diversification can reduce the correlation between assets, thereby contributing to a more optimal portfolio (Markowitz, 1952).

However, Barone (1983), Pukthuanthong and Roll (2009), and Bae, Elkamhi, and Simutin (2019) provide evidence that the benefits of international diversification, while still present, appear to be diminishing. This trend is partly attributed to globalization and the increasing concentration of multinational corporations' revenues in a similar set of countries (Goetzmann, Li, & Rouwenhorst, 2005). Supporting this view, Do, Nguyen, and Nguyen (2022) find that when a U.S. based company becomes a MNC, its return correlation with other MNCs increases, while its correlation with purely domestic stocks declines significantly. Similarly, Goetzmann et al. (2005) observe that during periods of globalization expansion (or contraction), national equity indexes tend to exhibit higher (lower) correlations with one another, thereby reducing (increasing) the potential benefits of international diversification. Interestingly, the integration of equity indexes among Eurozone countries was not significantly affected by the adoption of the euro (Bekaert, Harvey, Lundblad, & Siegel, 2013).

There is also evidence that domestic diversification can be effectively achieved at the state level, with certain U.S. states significantly outperforming others (Jory, Mishra, & Ngo, 2019). However, a key limitation of this study is that the analysis is based on the officially reported location of businesses, rather than the actual geographic distribution of their operations. This discrepancy may partially explain why certain states and companies

appear to outperform others (Jory et al., 2019).

The conceptual boundary of geographical diversification remains subject to debate. Pirinsky and Wang (2006) provide evidence that when companies relocate their headquarters, their stock returns tend to exhibit stronger correlations with the new host market and weaker correlations with their previous domestic market. This effect is particularly pronounced among smaller firms. These findings suggest that behavioral biases such as familiarity bias, social transmission, and herding may influence price movements, even when a firm's underlying operations remain largely unchanged (Bruner, Li, Kritzman, Myrgren, & Page, 2008; Pirinsky & Wang, 2006).

A significant explanatory factor may lie in the ownership structure of domestic versus foreign equity indexes. French and Poterba (1991) highlight that approximately 90% of equities in the U.S., Japan, Germany, and France were owned by domestic investors. In contrast, smaller markets tended to exhibit a higher proportional ownership by foreign investors (French & Poterba, 1991). There is also compelling evidence on how MNCs performance is shaped by their scale (i.e., the number of countries in which they operate) and scope (i.e., the extent of their operations). Qian and Li (1998) found that large U.S. MNCs tend to be most profitable when operating at a high scale but with moderate scope. Similarly, Fillat and Garetto (2015) showed that MNCs earned higher average returns compared to domestic firms during the 1979-2009 period.

These findings have important implications for portfolio risk diversification. The effectiveness of multinational corporations in this context depends on the extent to which the geographical distribution of their revenues, determined by both scale and scope, influences their risk profiles. Both theoretical and empirical research suggests that the risk premiums associated with MNCs are closely tied to the regions in which they generate revenue. However, if their returns become increasingly correlated due to similar patterns of international exposure, the benefits of diversification may be significantly diminished, even in the presence of broad geographical coverage.

A study by Miralles-Quiros and Miralles-Quiros (2017) provides strong evidence that incorporating return predictability into mean-variance optimization enhances the risk-adjusted performance of internationally diversified portfolios. Numerous studies have examined the benefits of international diversification as a tool for risk management, with extensive empirical evidence supporting its effectiveness (Agmon, 1973; Markowitz, 1952). In early work by Agmon (1973), correlations among countries' equity markets were already observable. However, their method for estimating stock prices was not based on regional revenue exposure but instead employed a common factor extraction approach. Specifically, stock prices were analyzed by isolating the influence of other countries through return regressions. Despite this, Agmon (1973) were unable to fully account for a residual pricing factor unique to each country, which they termed the "country factor".

To further develop the understanding of the country factor, the location of trade has been considered as a potential explanatory variable. Froot and Dabora (1999) address this residual factor by examining the role of trade location, incorporating investor behavior influenced by taxation, exchange rate fluctuations, voting rights, and other market frictions as possible explanations for the high residual values observed in Agmon (1973). Their analysis demonstrates that dual-listed stocks can diverge in price due to investor biases and market inefficiencies, leading to pricing differentials that extend beyond underlying fundamentals.

A possible extension of this idea is that market-wide noise may be partially attributed to the momentum anomaly, whereby assets that have recently outperformed tend to continue doing so, while past underperformers lag behind (Jegadeesh & Titman, 1993). This momentum effect appears to operate not only at the firm level but also across countries. For instance, Rouwenhorst (1998) find evidence of country-level momentum within European markets, where outperforming countries continued to generate superior returns relative to underperformers across all twelve countries analyzed. It is plausible that a similar effect may be present not only at the equity index level but also at the regional revenue level, whereby firms generating strong performance in certain regions may sustain that outperformance over time.

2.3 Valuation of multinational corporations and global risk

One of the most well-established methods for asset pricing is the capital asset pricing model (CAPM), which posits that the expected return of a security can be linearly explained by the risk-free rate, the expected return of the market, and the security's sensitivity to market movements, commonly referred to as beta (Lintner, 1965; Mossin, 1966; Sharpe, 1964; Treynor, 1962). Originally, CAPM was formulated to price individual stocks based on the domestic market in which they are listed Sharpe (1964). This framework was subsequently extended to a global setting by Solnik (1977) and Dumas and Solnik (1995), who introduced an international version of CAPM that incorporates the exchange rate risk premium when investing in foreign markets, thereby capturing additional sources of risk in asset pricing. Another variant of the international CAPM, despite sharing the same terminology differs from its predecessors by encompassing a broader set of factors. This model is more empirical than theoretical and accounts for the covariance with the global market (Engel & Rodrigues, 1989). Building on this latter model, Baillie and Cho (2016) found that equity market returns influence euro-dollar fluctuations, highlighting the significance of cross-border capital flows.

A key limitation of the CAPM is that, in an increasingly globalized world, relying on a single domestic market to price an asset may be somewhat outdated. Multinational corporations generate the majority of their revenues and maintain significant operations across multiple regions, rendering them, in theory, sensitive to various international markets rather than exclusively exposed to the systematic risk of a single national market (De Santis & Gerard, 1997; Elbannan, 2014; Fama & French, 2004). Although equity markets have become more integrated over time, asset pricing premiums remain substantially influenced by country-specific factors (Petzev, Schrimpf, & Wagner, 2016).

The CAPM was later extended into the well-established Fama-French three-factor model developed by Eugene F. Fama and Kenneth R. French, and subsequently into the Carhart four-factor model introduced by Mark M. Carhart. These models augment the CAPM by

incorporating additional factors: the size factor (Small Minus Big, SMB), the value factor (High Minus Low, HML), and, in the case of Carhart, a momentum factor, which posits that firms with strong recent performance are expected to continue outperforming in the near future (Carhart, 1997; Fama & French, 1992, 1993). These extensions have significantly enhanced the explanatory power and predictive accuracy of equity returns. The size factor suggests that smaller firms tend to yield higher expected returns due to their inherently higher risk profiles. Similarly, the value factor implies that value stocks, defined as those with high book-to-market ratios, tend to outperform growth stocks, often due to their stronger fundamental characteristics.

These multifactor models have also been evaluated in both global and domestic contexts. Asness, Moskowitz, and Pedersen (2013) developed a global three-factor model using data from 48 portfolios across various asset classes and found that both momentum and value premia appear consistently across global markets, with the two factors exhibiting a strong negative correlation. Griffin (2002) tested the Fama-French three-factor model by comparing country-specific and global specifications. Their findings indicate that domestic models more effectively explain the time-series variation in equity and portfolio returns, leading to the conclusion that global models do not offer meaningful advantages as substitutes. Similar conclusions are drawn by Fama and French (2012), who find that global multifactor models perform poorly in explaining regional portfolio returns. Their analysis, which covers 23 developed markets, demonstrates that lower pricing errors are achieved when using local models, especially when portfolios are sorted by size, value, or momentum. Taken together, these findings suggest that domestic factors are not fully captured within a global framework, and that understanding portfolio dependencies within specific regional contexts remains essential.

Ross (1976) introduced the arbitrage pricing theory (APT), a foundational asset pricing model that explains expected returns as a linear function of multiple risk factors. Although the model does not specify these factors a priori, it offers a framework through which they can be identified and empirically tested using real world data, such as macroeconomic indicators or other market-based variables. This framework has inspired exten-

sive research on factor testing in both domestic and international contexts. For instance, one study found that the risk premia associated with exposure to systematic risk vary across economies, suggesting that the slope of the CAPM should also differ between regions (Clyman, 1997).

This leads to the interim conclusion that none of these models perform particularly well when evaluated over extended periods (Petzev et al., 2016). Global factor models have generally underperformed in predicting asset prices, despite exhibiting marginal improvements during periods of heightened globalization (Petzev et al., 2016). A substantial portion of equity performance remains driven by local factors. Moreover, these models often fail to adequately capture the extent to which firms or indexes are economically linked to various regions, as they typically overlook the geographic composition of revenues, costs, or cash flows. Consequently, they neglect the fact that multinational corporations with broader international exposure are expected to exhibit lower beta values due to reduced nonsystematic risk (Barone, 1983). Although investors remain unable to fully diversify their risks across markets because policy and macroeconomic risks often transcend national borders, international diversification still contributes to lower beta values (Lam, Zhang, & Zhang, 2020). Surprisingly, many studies continue to overlook the role of MNCs' revenue and cash flow distributions across geographic regions.

Modern asset pricing theories are fundamentally grounded in the concept of risk premia, which posit that higher levels of risk are associated with higher expected returns. Empirical evidence suggests that expected risk premia tend to rise during economic contractions and decline during expansions, as investors demand greater compensation amid heightened uncertainty (Ferson & Harvey, 1991). While such models may perform adequately under certain conditions, they often fail under others (Ferson & Harvey, 1991). Nevertheless, a firm's fundamental performance remains a consistently relevant factor. When fundamentals improve or are expected to improve, these changes are typically reflected in stock prices. For investors who actively monitor such metrics, the regional distribution of revenues is critical not only for forecasting earnings but also for assessing region-specific risk exposure. Higher perceived risks are often associated with elevated discount

rates, as the weighted average cost of capital (WACC) tends to rise under such conditions (Damodaran, 2012). As a result, companies with greater exposure to developing foreign markets may be associated with a higher cost of equity.

In the study by Qian and Li (1998), ”high global market diversifiers” (HGM), defined as firms generating more than 70% of their revenue from foreign countries, and ”low global market diversifiers” (LGM), with less than 50% of revenue derived from abroad, exhibited lower risk-adjusted performance compared to ”medium global market diversifiers” (MGM), which derive 50-70% of their revenue from international markets. This finding indicates a non-linear relationship between equity performance and the scope and scale of a company’s international operations. Each region in which MNCs operate carries a distinct degree of risk, often tied to macroeconomic factors such as inflation, GDP fluctuations, and other systemic variables.

Gala, Pagliardi, and Zenios (2023) demonstrated that investors demand higher expected returns for equities with greater exposure to political uncertainty. Political risk can influence asset returns either by increasing the discount rate or by affecting expected cash flows (Gala et al., 2023). The geopolitical risk index (GPR), developed by Caldara and Iacoviello (2022), captures geopolitical uncertainty across multiple countries and regions by analyzing the frequency of negative expectations in top-tier newspapers, effectively summarizing perceived uncertainty. Their findings show that higher GPR values are associated with lower firm-level investment and an increased likelihood of GDP contraction. Using a similar methodology, Baker, Bloom, and Davis (2016) constructed the economic policy uncertainty (EPU) index, which also provides strong evidence that political uncertainty is a significant explanatory variable for stock market volatility. Consequently, companies generating revenue from regions characterized by high political uncertainty may be priced at a discount relative to firms operating primarily in more stable economies (Gala et al., 2023), as such environments are often associated with elevated risks related to geopolitical blocs, international relations, currency volatility, and inflation. This pattern is particularly evident in developing countries, which tend to carry higher risk due to weaker bureaucratic institutions (Lam et al., 2020), whereas developed countries

are more dependent on the stability and effectiveness of their governments (Lam et al., 2020).

This establishes a fundamental assumption: the operations of MNCs are closely tied to the geographic scope and scale of their activities, rendering them increasingly sensitive to both global and local factors specific to the regions in which they operate (Qian & Li, 1998). Accordingly, if a firm's exposure to regional risks is proportional to its revenue distribution, such firms should not be associated with a single market beta. Instead, their systematic risk should theoretically be modeled as an aggregate of the market returns of the regions in which they are active. This concept forms the basis for the empirical testing conducted in this research.

Finally, beyond company fundamentals, future outlooks, and asset pricing models, behavioral factors also influence asset pricing and cannot be fully explained through traditional valuation approaches. One of the most notable and relevant in the context of this analysis is the familiarity effect, which contributes to home and local bias. This bias can result in the higher pricing of domestic equities, as investors tend to assign greater value to companies based in their own countries (French & Poterba, 1991; Portes & Rey, 2005).

3 Fundamentals of indexes

Before delving deeper into the subject, it is essential to understand the structure and methodology of major equity indexes, as this forms the foundation for meaningful comparisons. This chapter provides a focused overview of the construction of key indexes, including the Euro Stoxx 50, MSCI AC Asia-Pacific, MSCI AC America, MSCI AC Europe and Middle East, and MSCI AC World Index (WI), with particular emphasis on the Euro Stoxx 50, which serves as the central case for the quantitative analysis. Drawing primarily on the Stoxx Index Methodology Guide (Portfolio Based Indices, September 2024) and supplemented by the Stoxx Index Calculation Guide (August 2024), the overview highlights the most relevant aspects of the Euro Stoxx 50's design to establish a sufficient understanding for the purposes of this study (Deutsche Börse Group, 2024a, 2024b).

3.1 Fundamentals of Euro Stoxx 50

The Euro Stoxx 50 is among the most widely followed equity indexes in Europe, comprising leading companies across major supersectors and including some of the most actively traded equities within the eurozone. As such, it serves as a robust benchmark for evaluating the performance of European equity markets. In this study, the index is employed to examine how regional revenue exposure influences the pricing of eurozone-listed equities and to support comparisons with broader equity market performance. A clear understanding of the index's composition is essential for interpreting the subsequent analysis.

3.1.1 General overview of the index

The base value of the Euro Stoxx 50 index is set at 1000 as of December 31, 1991. Euro Stoxx indexes are structured hierarchically, with the Euro Stoxx Total Market Index (TMI) serving as a foundational component. The TMI captures nearly 95% of the eurozone's free-float market capitalization and forms the basis for several derived indexes, including

the Euro Stoxx 50. The Euro Stoxx 50 itself covers approximately 60% of the TMI's free-float market capitalization, offering a focused yet comprehensive view of the eurozone's equity landscape.

The index can also be segmented into country-specific or country-excluded sub-indexes such as the Euro Stoxx 50 Subindex France, enhancing its flexibility for use in constructing ETFs, options, and benchmarks. This versatility contributes to its widespread popularity in European financial markets.

As illustrated in figure 1, the weighting of companies by their respective countries evolved significantly over the five-year period from the end of September 2019 to the end of March 2024. The index is primarily composed of French and German firms, though no single country may exceed 15 constituents, as stipulated by index rules. Despite this cap, the index remains heavily tilted toward these two economies. Notably, during the sample period, French companies overtook German firms in total index weight, reflecting their relative outperformance and growing influence in index construction. Meanwhile, certain eurozone countries such as Portugal, Luxembourg, and Austria had no representation in the index.

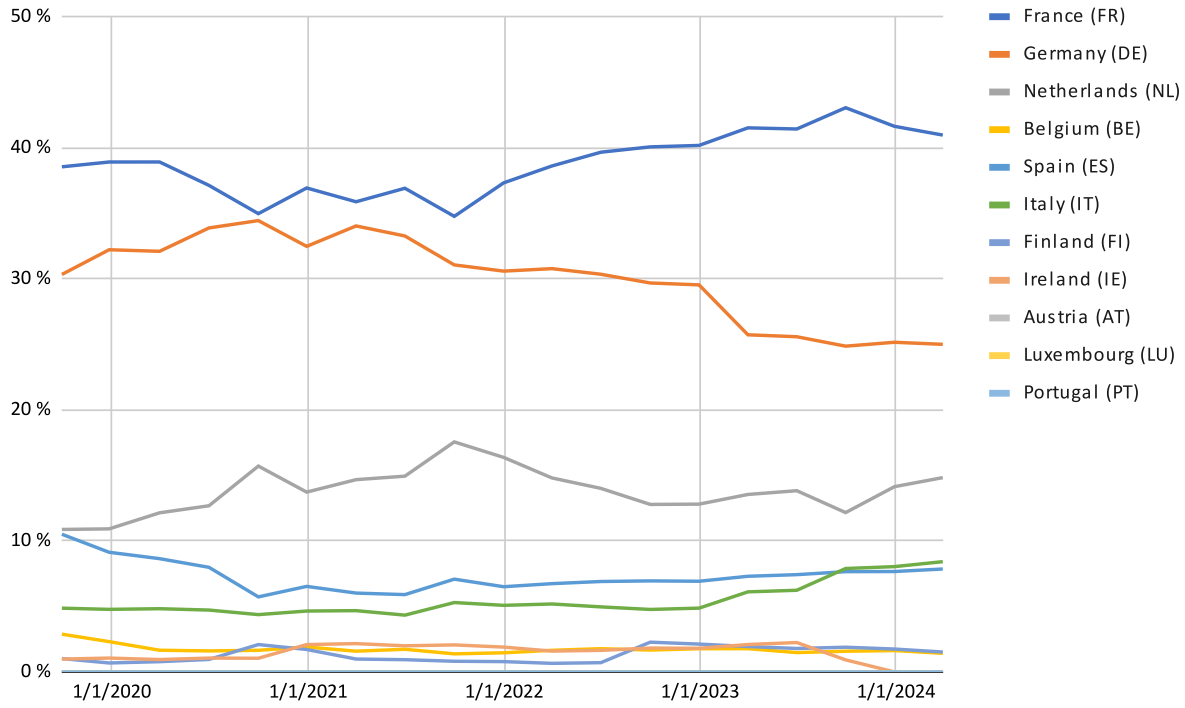

Figure 1. Country weights in the Euro Stoxx 50 based on components' ISIN-codes.

Similarly, we can analyze the industry weights over the same period, from the end of September 2019 to the end of March 2024. Industry classification is based on the Industry Classification Benchmark (ICB), which is also used in the construction of the Euro Stoxx 50 index. As shown in figure 2, the total portfolio weight of the consumer discretionary industry has exhibited steady growth. In contrast, the significant decline in the basic materials sector in January 2023 can be attributed to the proportionally large delisting of Linde Plc from the DAX and STOXX indexes (Deutsche Börse Group, 2023).

The ICB classification follows a hierarchical structure, which allows for varying levels of detail. It begins with 19 supersectors, followed by 41 sectors and 114 subsectors, becoming increasingly specific at each level (Vermorken, 2011). Tables 16 and 17 in the appendix section provide further detail and illustrate the extent to which the most heavily weighted industries contribute to the overall structure of the index.

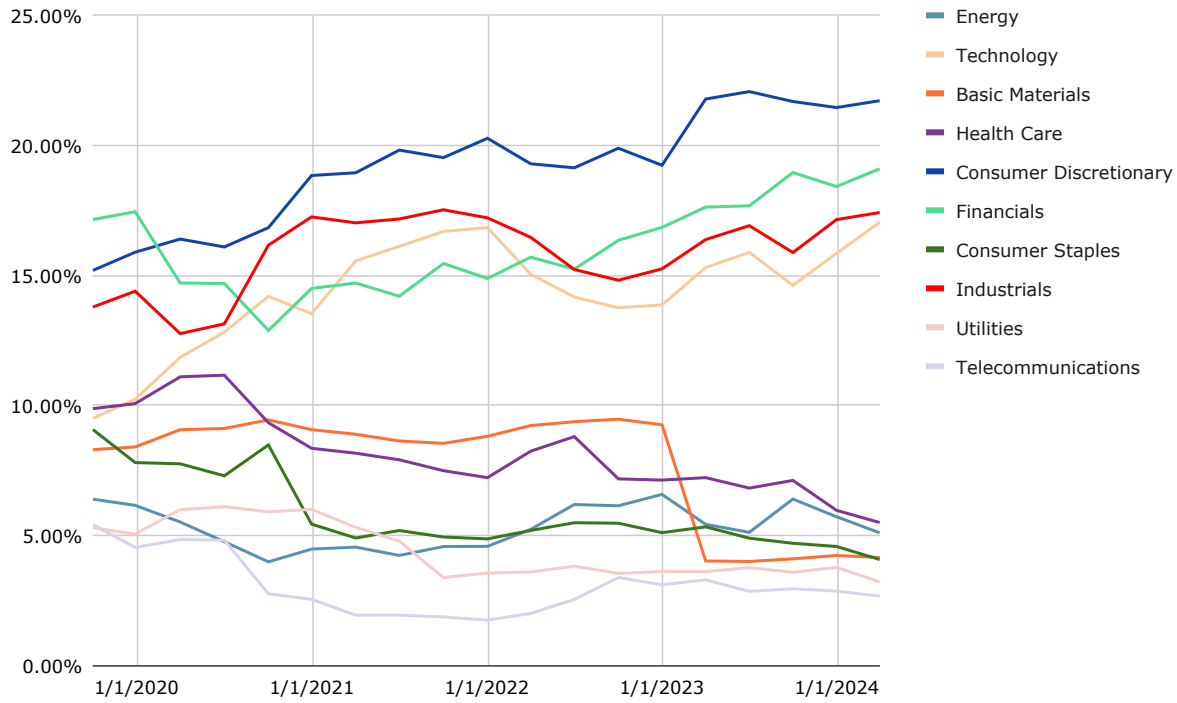

Figure 2. The weights of the Euro Stoxx 50 by industry (ICB classification).

3.1.2 General principles, coverage and characteristics

A general principle underlying all STOXX indexes is that methodological changes may be implemented to ensure that the index continues to fulfill its intended purpose and remains consistent with its rationale. To this end, STOXX actively engages with third parties and market participants. In addition, the index provider considers political and economic developments, shifts across industries, and the performance of the index calculation process itself. These factors may prompt updates to the methodology, which are transparently documented in publicly available guides.

As of September 2024, the investable universe for the Euro Stoxx 50 was significantly smaller than the total number of eurozone member countries. This is due to strict eligibility criteria applied to both markets and companies, as outlined in table 1. The index is derived from a carefully curated selection of eurozone companies that trade exclusively

in euros, across eight primary exchanges. Eligibility requires compliance with rigorous conditions, including size and liquidity thresholds, macroeconomic stability, the absence of capital flow restrictions, and adherence to principles of good governance and political transparency. Despite these stringent requirements, the Euro Stoxx 50 effectively captures the performance of the region's leading firms across key economic sectors.

Table 1. Euro Stoxx 50 investable universe (Deutsche Börse Group, 2024).

EURONEXT Dublin (IE)	EURONEXT Amsterdam (NL)
EURONEXT Lisbon (PT)	Bolsa De Madrid (ES)
EURONEXT Milan (IT)	Deutsche Boerse (DE)
EURONEXT Paris (FR)	NASDAQ Helsinki (FI)
EURONEXT Brussels (BE)	Vienna Stock Exchange (AT)

The Euro Stoxx 50 index accounts for changes in eurozone membership, making adjustments when countries join or exit the euro area. Such modifications are announced in a timely manner, based on prevailing market conditions. The index is reviewed annually, with updates reflecting corporate actions (e.g. mergers or acquisitions), liquidity considerations, and size rankings relative to peer companies.

To minimize turnover and preserve index stability, the Euro Stoxx 50 employs a buffer rule during its selection process. Specifically, the 40 largest eligible stocks are initially selected. The remaining positions are then filled from companies ranked 41st to 60th, based on a combination of factors including size, sector representation, and country diversification, until the total number of constituents reaches 50. This "40-60 buffer rule" helps to reduce frequent changes in index composition and ensures a consistent structure.

An annual review and potential rebalancing occur at the beginning of September. Five trading days prior to the review, weighting factors are announced, and closing prices from the day before the announcement are used in calculations. Additionally, to qualify for inclusion, constituents must meet a minimum average daily trading value, which serves

as a liquidity threshold. This threshold is flexible and may be adjusted to reflect overall market activity.

The country classification of Euro Stoxx 50 components is determined by their primary listing location and country of incorporation. To be eligible for inclusion in eurozone indexes, companies must be listed in a eurozone country and trade in euros. In addition to geographic classification, companies are also categorized by the primary sector in which they operate. For sector analysis within the Euro Stoxx 50, the previously mentioned ICB is employed, providing a standardized framework for industry grouping.

3.1.3 Methodological framework

The Euro Stoxx 50 is calculated as a free-float market capitalization-weighted index, following a Laspeyres-type methodology (Deutsche Börse Group, 2024b). To preserve diversification, individual constituent weights are capped at 10%. In order to ensure investability, eligible stocks are screened based on liquidity, primarily measured through average trading volume and free-float levels (Deutsche Börse Group, 2024b).

A key component of the index methodology is the application of a free-float adjustment factor. This factor modifies a company's total share count by excluding shares that are not freely available for trading. These may include holdings related to cross-ownership, government or private control, and other restricted shares. Specifically, any long-term holding equal to or exceeding 5% is excluded from the float-adjusted share count. This approach provides a more accurate measure of market-accessible equity and reflects the actual investable opportunity available to market participants.

3.2 MSCI indexes

The MSCI All Country (AC) indexes serve as broad benchmarks that reflect regional variations in equity market performance. In this study, the MSCI AC Asia-Pacific, MSCI AC

Europe and Middle East, MSCI AC America, and MSCI AC World Index are employed to evaluate the growth of Euro Stoxx 50 constituents based on their respective regional revenue exposures. These indexes were selected due to their strong regional representativeness, which supports a meaningful analysis of Euro Stoxx 50 performance through the lens of geographic revenue attribution.

The MSCI indexes are well-diversified across both countries and sectors, with compositions that are broadly comparable to that of the Euro Stoxx 50. This makes them suitable proxies for model testing within the context of this study. Furthermore, as of 2022, Russian companies have been removed from all underlying index constituents considered in this analysis due to the Russia-Ukraine war (MSCI Inc., 2022).

However, a key limitation of this approach must be acknowledged: the constituents of MSCI regional indexes, such as those of the Euro Stoxx 50, often derive a portion of their revenues from outside their respective regions. This introduces a potential for recursive attribution and circular reasoning in the analysis. Nonetheless, because the majority of revenues within these indexes tend to be concentrated in their target regions, they remain a reasonable and effective proxy for regional economic exposure and performance (Melas et al., 2019).

3.3 Differences between indexes

The purpose of this section is to provide a brief analysis of the fact sheets for each equity index and to highlight the key differences among them MSCI Inc. (2025a, 2025b, 2025c, 2025d). Due to data availability constraints for the year 2024, the analysis is based on data as of March 31, 2025. A more granular comparison is deemed unnecessary, given the substantial differences in constituent counts across indexes. As of the end of March 2025, the MSCI Europe and Middle East Index comprised 414 constituents, the MSCI AC Asia Pacific Index 1,256, the MSCI AC Americas Index 741, and the MSCI World Index 2,558. These figures underscore the breadth of coverage and support the use of these indexes

as robust proxies for tracking regional equity performance over time.

As shown in table 2, the MSCI AC Americas Index posted the highest 5-year Sharpe ratio, indicating the most favorable risk-adjusted return among the indexes analyzed. It was followed by the MSCI World Index, largely due to its significant exposure to U.S. equities. Indeed, over half of the World Index's constituents are U.S.-based, as reported in table 3. The strong performance of U.S. equities over the past decade has been a major driver of this trend.

Table 2 also indicates that the MSCI AC Americas Index exhibited the lowest turnover percentage, suggesting that its constituent composition remained the most stable over the observed period. In contrast, the Euro Stoxx 50 demonstrated the highest variance, reflecting greater fluctuations in its component structure and potentially higher sensitivity to market or corporate events.

Table 2. Index risk and return characteristics as of March 31, 2025.

Index	Turnover (%)	Annualized Std Dev (%)			Sharpe Ratio			Max DD (%)	Max DD Period
		3 yr	5 yr	10 yr	3 yr	5 yr	10 yr		
MSCI Europe and Middle East	3.63	17.87	17.65	16.42	0.28	0.68	0.33	35.60	2020-01-17–2020-03-23
MSCI AC Asia Pacific	4.24	16.76	15.33	14.84	0.01	0.45	0.27	57.63	2007-11-01–2009-03-09
MSCI AC America	2.05	17.49	17.17	15.62	0.31	0.92	0.68	55.14	2007-10-09–2009-03-09
MSCI ACWI	2.60	16.29	15.84	14.83	0.26	0.84	0.55	58.06	2007-10-31–2009-03-09
Euro Stoxx 50	2.80	15.90	18.60	—	0.40	0.60	—	—	—

Table 3. Top 5 country weights by index (based on company headquarters) as of March 31, 2025.

Index	Country 1	Country 2	Country 3	Country 4	Country 5
Euro Stoxx 50	38.5% France	29.0% Germany	12.6% Netherlands	8.4% Spain	8.3% Italy
MSCI Europe & ME	22.39% UK	17.05% France	14.83% Germany	14.73% Switzerland	6.52% Netherlands
MSCI AC Asia Pacific	31.4% Japan	20.9% China	12.4% India	11.3% Taiwan	9.6% Australia
MSCI AC America	94.9% USA	4.1% Canada	0.7% Brazil	0.3% Mexico	0.07% Chile
MSCI ACWI	64.6% USA	4.9% Japan	3.4% UK	3.2% China	2.8% Canada

Although the Euro Stoxx 50 demonstrated solid absolute performance among the indexes considered, its returns remain significantly below those of the MSCI AC Americas Index, as illustrated in figure 3. The figure presents the relative performance of regional MSCI AC indexes compared to the Euro Stoxx 50. Notably, the monthly returns of the MSCI AC Americas Index were consistently higher than those of other regions over the period from 2015 to 2025.

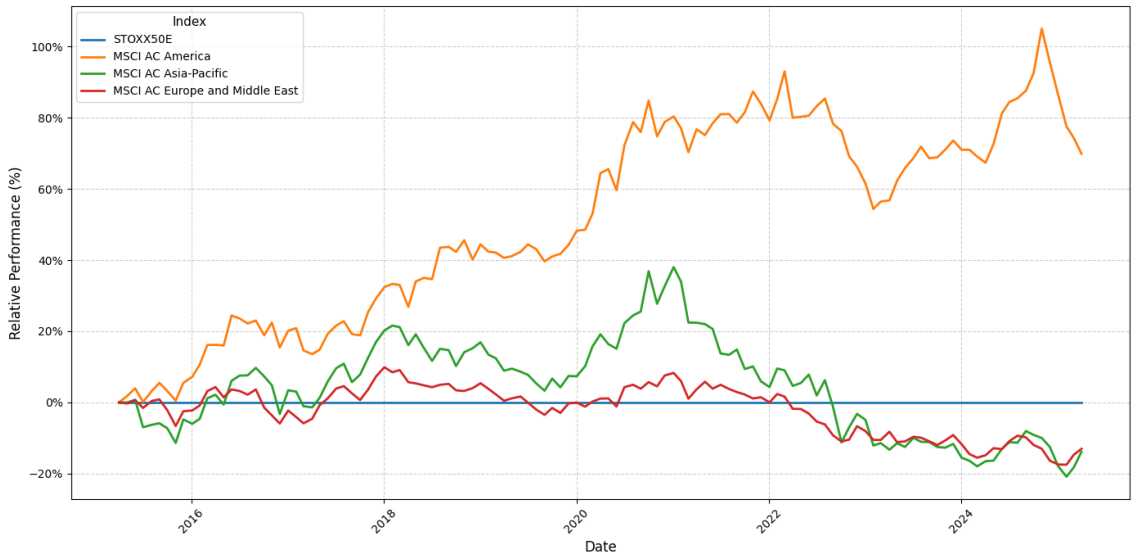

Figure 3. Cumulative monthly returns of each MSCI regional index compared to the Euro Stoxx 50.

From a sectoral analysis perspective, notable differences emerge among the indexes, as shown in table 4. The MSCI AC Americas Index, in particular, is heavily weighted toward the information technology sector, which accounts for approximately 28.4% of its total composition. This concentration likely contributes to the index's strong performance, driven by the exceptional returns of stocks related to artificial intelligence, even in the face of global uncertainties such as the COVID-19 pandemic and the Russia-Ukraine war (Yadav, Abedin, Sinha, & Arya, 2024). Despite these distinctions, all indexes maintain a significant allocation to the financials sector, followed by either information technology or industrials. It is also worth noting that the industrials sector holds a comparatively smaller weight in the MSCI AC Americas Index than in the other indexes, which reflects regional differences in economic structure and sectoral focus.

Table 4. Top 5 industry weights by Euro Stoxx 50 as of March 31, 2025.

Industry	Euro Stoxx 50		MSCI Europe		MSCI AC Asia		MSCI AC America		MSCI ACWI	
	Industry	Weight (%)	Industry	Weight (%)	Industry	Weight (%)	Industry	Weight (%)	Industry	Weight (%)
1	Financials	21.4	Financials	22.5	Financials	22.6	Info Tech	28.4	Info Tech	23.4
2	Info Tech	16.0	Industrials	17.6	Info Tech	18.7	Financials	15.5	Financials	18.1
3	Industrials	15.0	Health Care	14.6	Consumer Disc.	15.6	Health Care	10.7	Industrials	10.6
4	Consumer Disc.	14.0	Consumer Disc.	8.6	Industrials	12.0	Consumer Disc.	10.0	Consumer Disc.	10.6
5	Health Care	6.1	Info Tech	7.5	Comm. Services	9.3	Industrials	8.8	Health Care	10.3

Having outlined the fundamental characteristics and structural differences among the indexes, we now turn to the data and methodology section. This part of the analysis seeks to deepen our understanding of how the geographical revenue distribution of multinational corporations, specifically those within the Euro Stoxx 50 can help explain the index's overall performance. In particular, we examine how this performance compares to that of a broader regional MSCI indexes, which represent aggregated equity returns across the corresponding regions.

4 Data and methodology

This chapter outlines the data sample used in the research, along with the principles and methodology applied to process the sample into a format suitable for hypothesis testing and descriptive analysis. The Euro Stoxx 50 (SX5E) was selected as the case sample based on several key considerations. First, the SX5E is one of the most widely followed equity indexes and represents a substantial portion of the broader Euro Stoxx market, while comprising a relatively limited number of constituents, as previously noted. This makes the dataset more manageable for detailed analysis. The extracted data lack a standardized structure, as companies frequently report regional financials inconsistently due to differing national accounting standards, which may also evolve over time within the same firm. Therefore, focusing on an index with approximately 50 constituents helps reduce the risk of data-related errors during the processing phase.

Second, the SX5E is designed to reflect both industry diversification and geographical representation across eurozone countries, providing a balanced view of the broader regional market. Finally, and most importantly, the data were obtained directly from STOXX, a first-party source, ensuring a high level of reliability and further justifying the selection of this sample.

4.1 Data collection

Initially, the most valuable data for this research was access to historical index weight information. Such data is rarely publicly available, as most sources provide only current weights, with historical datasets often locked behind substantial paywalls. However, STOXX supplied official data on Euro Stoxx 50 index weights, covering the period from September 30, 2019, to June 28, 2024, with quarterly granularity. This dataset also represented the longest available time series provided by the data vendor, which imposed certain limitations on the analysis. Nevertheless, the selected time frame is particularly relevant, as it encompasses major global events such as the COVID-19 pandemic, the

Russia-Ukraine war, and Brexit, among others.

Information on regional sales exists at the company level, and country-by-country reporting (CbCR) is intended to promote fairer taxation of multinational corporations by reducing income-shifting practices (Fuest, Hugger, & Neumeier, 2022; Joshi, Outslay, Persson, Shevlin, & Venkat, 2020). However, regional revenue data are not always publicly available, particularly for firms in the financial sector, which often do not report such information.

Nonetheless, large eurozone MNCs frequently disclose regional sales figures in their quarterly or annual reports, often as a voluntary measure to enhance transparency and public image. Due to the non-mandatory nature of these disclosures, the structure of regional revenue reporting varies considerably: some companies report on a regional basis, while others provide country-specific data; some include this information only in annual reports, while others do so in both annual and quarterly filings. The data used in this study were primarily obtained from Bloomberg, with supplementary reviews of official company reports to ensure accuracy and completeness. This heterogeneity in reporting remains the primary constraint on the precision of the analysis, as revenue figures must often be aggregated and compared across broader regions. Nevertheless, increased transparency in corporate reporting has made such analyses feasible, which would not have been possible in the past.

4.2 Sample description

This study primarily examines continuous variables, including index prices, regional revenues, and component weights. These variables are essential for analyzing the distribution of regional revenues and their interactions with stock prices, serving as the foundation for testing the research hypotheses.

Table 5 presents descriptive statistics analyzing the occurency with which components

from specific industries appear over the period from September 30, 2019, to June 28, 2024. The analysis reveals that the majority of companies in the sample period belong to either the consumer discretionary or financial industries, which together account for a combined mean weight of 35.5%. In contrast, industries such as telecommunications and utilities are underrepresented, with a total average weight of only 8.42%. Furthermore, the standard deviation of industry weights is notably higher in sectors such as technology and basic materials, which may also exhibit greater price volatility during the observation period. A more detailed breakdown is provided in appendix table 18.

Table 5. Summary of component weights and occurrences.

Component	Occurrence (N)	N%	Mean weight	Min weight	Max weight	Median Weight	SD
Technology	78	7.80%	14.57%	9.51%	18.53%	14.83%	2.25%
Consumer Discretionary	211	21.10%	19.22%	15.19%	22.07%	19.41%	2.13%
Health Care	76	7.60%	8.01%	5.50%	11.16%	7.70%	1.64%
Industrials	164	16.40%	15.93%	12.76%	17.52%	16.42%	1.48%
Basic Materials	54	5.40%	7.50%	3.90%	9.47%	8.73%	2.33%
Financials	206	20.60%	16.28%	12.88%	19.10%	16.03%	1.84%
Energy	40	4.00%	5.32%	3.99%	6.58%	5.28%	0.80%
Utilities	48	4.80%	4.37%	3.22%	6.10%	3.77%	1.05%
Telecommunications	42	4.20%	3.05%	1.74%	5.42%	2.86%	1.07%
Consumer Staples	81	8.10%	5.73%	4.08%	9.07%	5.19%	1.48%

4.3 Data processing

Due to inconsistencies in the reporting of regional revenues across companies, the analysis aggregates data into broader regional categories to ensure comparability. Specifically, when revenues are reported at the country level, they are consolidated into one of the following larger regions: EMEA, APAC, or the Americas. In cases where companies report revenues ambiguously using labels such as “hedging,” “not disclosed,” or “other”, these entries cannot be reliably assigned to a specific region and are therefore grouped into an “other” category.

Additionally, some companies report revenue data from select countries (e.g., Germany or the United States) while aggregating all other regions under a category such as “rest of the world.” These instances are treated as a distinct fifth category in the analysis, also

labeled “rest of the world.” The outlined data processing steps ensure the construction of a clean and reliable panel dataset suitable for empirical analysis.

4.4 Methodology

The methodological framework is illustrated in figure 4, providing a visual overview of the analytical approach. Each constituent’s revenues are initially allocated to previously mentioned predefined regions: EMEA, APAC, Americas, rest of the world, and other. These revenues are then converted into percentages of total revenue for each company, ensuring they sum to one. Importantly, the effective weight of each constituent within a given region varies according to the proportion of its revenues originating from that region.

Once all constituents’ regional exposures are computed, they are aggregated by weighting each constituent’s regional exposure by its corresponding weight in the Euro Stoxx 50 index on a quarterly basis. This procedure yields a dataset that decomposes the Euro Stoxx 50 index into five regional revenue groups, forming a robust foundation for the subsequent analysis.

Next, the performance of MSCI indexes corresponding to these regions is compared to the actual returns of the Euro Stoxx 50 index on a monthly, weekly, and daily basis. In essence, a panel data regression is conducted, where the Euro Stoxx 50 return serves as the dependent variable, and the independent variables are the total proportional revenues from each region, multiplied by the return of the MSCI index associated with that region.

Mathematically, the following equations are used to process the data and construct the panel dataset that underpins the hypothesis testing and analysis. Equation 3 shows that each company’s regional revenue shares sum to one. When the regional revenues are aggregated across all constituents and weighted by their respective index weights.

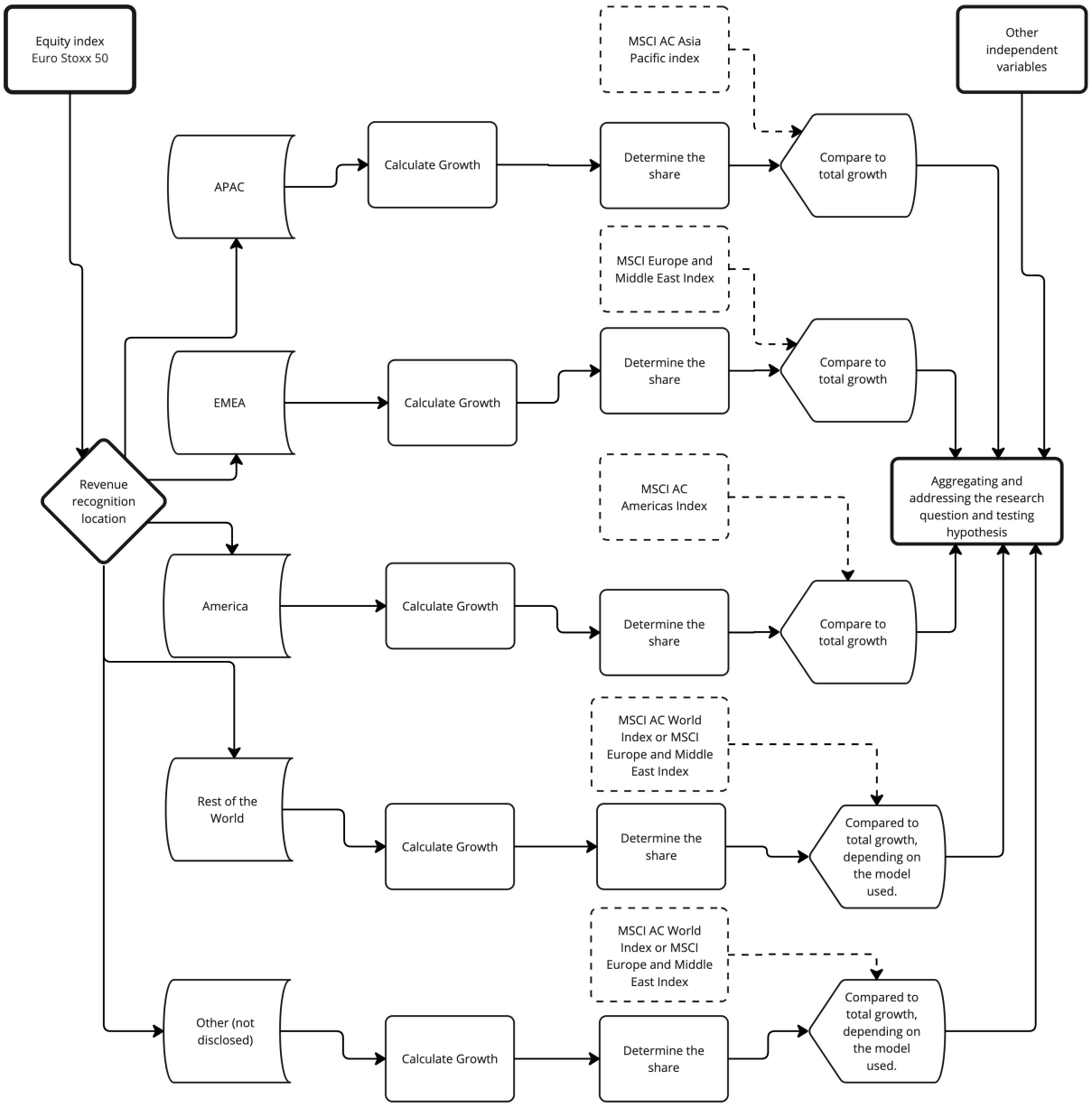

Figure 4. Overview of the methodological framework.

$$\sum_{r=1}^{R} S_{i,r} = 1, \tag{3}$$

where R is the total number of distinct revenue groups, and $S_{i,r}$ denotes the share of total revenue that company i generate from revenue group r.

To calculate the index-level regional proportions, the regional revenue shares of all constituents must be aggregated, leading to equation 4:

$$\sum_{r=1}^{N} S_{i,r} w_{i,r} = W_r, \tag{4}$$

where N is the total number of constituents, and $w_{i,r}$ is the corresponding weight of each component in the Euro Stoxx 50. This results in W_r, which represents the unnormalized aggregate weight of total revenue attributed to region r across all companies.

A small minority of companies, representing less than 5% of the index weight, do not report revenues by region. To account for this, the reported regional revenue shares are proportionally upscaled through a normalization procedure. This adjustment assumes that the unreported portion follows the same average regional distribution as the reporting companies. By redistributing the missing share proportionally, this approach simplifies subsequent analysis and ensures that the total of all regional revenue shares sums to one, equation 5.

$$\sum_{r=1}^{R} \tilde{W}_r = \sum_{r=1}^{R} \frac{W_r}{w^{\text{reported}}} = 1 \tag{5}$$

Here, W_r denotes the aggregated regional revenue for constituents that report revenues in region r. The term w^{reported} represents the total proportion of Euro Stoxx 50 con-

stituents that disclose any regional revenue data. The normalized share $\tilde{W}_r$ rescales these proportions so that the sum across all regions equals one, allowing us to approximate the regional distribution of the full index despite missing disclosures from some companies.

At this stage, having established the proportional normalized revenue shares of the Euro Stoxx 50 across regions, the analysis proceeds as follows. First, the log return of each MSCI regional index is calculated, as defined in equation 6.

$$R_{i,t} = \ln\left(\frac{P_t}{P_{t-1}}\right) \tag{6}$$

Where P_t and P_{t-1} represent the price of the index i at time $t-1$ and t, respectively, and $R_{i,t}$ is the log return for index.

Then, for each time period t, the return of each regional index is multiplied by the Euro Stoxx 50's corresponding revenue exposure to that region, as shown in equation 7. For example, if in 2019 the Euro Stoxx 50 derived 30% of its revenue from the EMEA region, this share is multiplied by the growth of the MSCI AC Europe and Middle East index. These equations result in the aggregate model equation, which is constructed by taking into account annual index regional revenue proportions, index constituents' weights on a quarterly basis, MSCI index performance, and normalization when companies in the Euro Stoxx 50 do not report regional revenue data. This eventually leads to equation 7.

$$R_t^{\text{Model}} = \sum_{r=1}^{R} \tilde{W}_r \cdot R_{i,t} \tag{7}$$

This summation aggregates the weighted regional returns across all regions, resulting in a model R_t^{Model}, which will be evaluated as an explanatory framework for the Euro Stoxx 50's returns.

Finally, following the preceding steps, a panel dataset is constructed in which the dependent variable is the return of the Euro Stoxx 50 index, and the explanatory variables are the proportional revenue shares, each multiplied by the performance of the corresponding MSCI regional index. However, due to the ambiguous reporting of revenues under categories such as “rest of the world” and “other,” where precise geographical origins are not specified, multiple model specifications are tested to account for this uncertainty:

- **Model (1):** Combines the “rest of the world” and “other” categories and applies the MSCI AC WI index to their aggregated revenue share.
- **Model (2):** Applies the MSCI AC Europe and Middle East index to both the “rest of the world” and “other” revenue categories.
- **Model (3):** Assigns the “rest of the world” category to the MSCI AC WI index, while the “other” category is matched with the MSCI AC Europe and Middle East index.
- **Model (4):** Reverses the assignments in Model (3), applying the MSCI AC Europe and Middle East index to the “rest of the world” category and the MSCI AC WI index to the “other” category.

For the quantitative method, panel data regression is proposed, as it is well suited to the structure of the dataset, which includes temporal observations, a dependent variable, and multiple explanatory variables. Specifically, the ordinary least squares (OLS) version of the panel data regression model is specified, as shown in equation 8, and results will be compared across models. The analysis will assess how effectively each model explains the performance of the Euro Stoxx 50 index. In addition, the correlation between model-predicted returns and actual SX5E returns will be examined and contrasted with the direct correlations among the underlying indexes. This comparison will facilitate an evaluation of whether incorporating firms’ regional revenue weights enhances the model’s predictive capability.

$$R_t^{\text{SX5E}} = \alpha + \beta R_t^{\text{Model}} + \varepsilon_t \tag{8}$$

Where R_t^{SX5E} is the return of the Euro Stoxx 50 index at time t, α is the regression intercept representing, β measures the sensitivity of the Euro Stoxx 50 to the modeled return, and ε_t is the error term capturing the portion of the Euro Stoxx 50 return not explained by the model. A statistically significant β close to one would suggest strong alignment between the model and actual index performance.

5 Results and discussion

This section evaluates the predictive accuracy of the models in forecasting Euro Stoxx 50 returns. The analysis begins by examining the regional distribution of revenue exposures. Subsequently, the dataset is tested for heteroskedasticity to determine whether the reported p-values are valid indicators or require adjustment. Autocorrelation is also assessed to further ensure the robustness of the regression assumptions.

Model performance is assessed by comparing the correlation coefficients between predicted and actual returns. The analysis investigates whether incorporating regional revenue exposures and aggregated, proportionally weighted MSCI returns enhances predictive accuracy relative to models relying solely on unadjusted, broad MSCI indexes. This comparison is conducted across monthly, weekly, and daily return frequencies. Ordinary least squares regressions are employed, using Euro Stoxx 50 returns as the independent variable, to evaluate the relative performance of each model specification. The chapter concludes with a synthesis of the key findings and a discussion of limitations, including potential methodological refinements that could improve the robustness and explanatory power of the analysis.

5.1 Euro Stoxx 50 revenue exposure

Understanding the distribution of regional revenues across geographic areas is a cornerstone of this analysis, as it directly informs the model construction outlined in the methodology section. The underlying premise is that different regions are associated with distinct risk premia, which may enhance the predictive accuracy of the models. This subsection illustrates how the regional revenue composition of the Euro Stoxx 50 has evolved over time.

As shown in figure 5, the proportional distribution of revenues across regions has remained relatively stable throughout the sample period. In particular, the shares attributed

to the rest of the world and other categories have exhibited consistent levels. However, a notable upward trend occurred between the third quarter of 2019 and the end of the fourth quarter of 2021, during which revenues from Asia-Pacific countries steadily increased and became proportionally more significant for the multinational constituents of the Euro Stoxx 50. This trend reversed around the midpoint of the sample period, followed by a decline in Asia-Pacific revenue contributions. This shift was likely influenced by the onset of the full-scale military conflict between Russia and Ukraine, which appears to have disrupted the geographic revenue distribution of the index constituents through supply chains. Other contributing factors could include tightened monetary policy and the diminishing effects of the temporary post-COVID-19 demand boost.

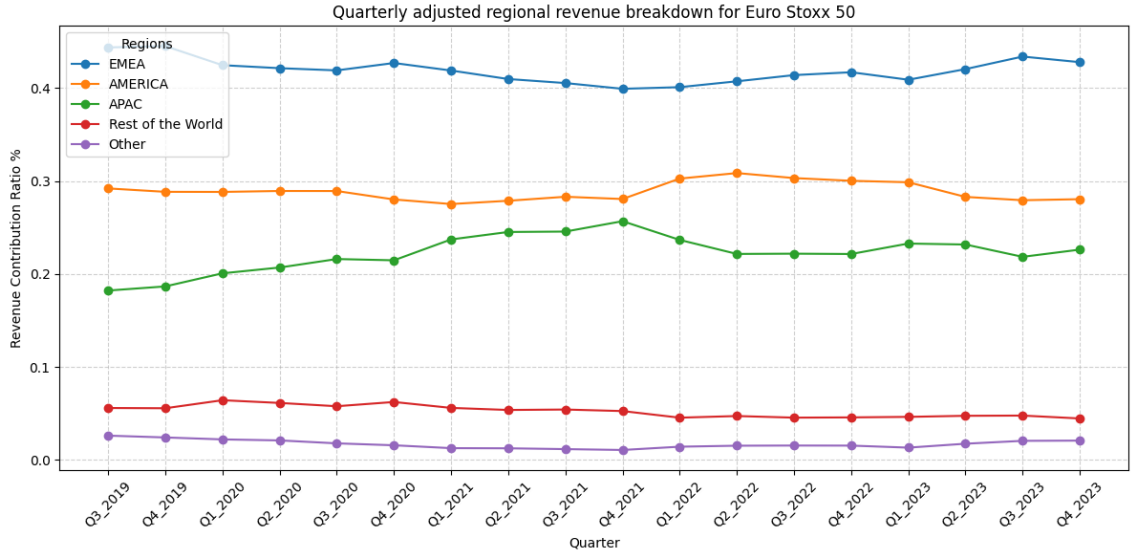

Figure 5. Quarterly adjusted regional revenue breakdown for Euro Stoxx 50.

5.2 Heteroskedasticity and autocorrelation

Before proceeding with the empirical analysis, it is essential to test for homoskedasticity or heteroskedasticity to determine whether the standard errors can be considered reliable White (1980). As a preliminary step, log returns are employed to promote approximate normality and mitigate potential heteroskedasticity. Subsequently, formal tests for heteroskedasticity are conducted using both White's test and the Breusch-Pagan test to evaluate the validity of the error terms.

Table 6 presents the results of these tests. For all independent variables, the White test yields p-values below 0.05, leading to the rejection of the null hypothesis of homoskedasticity. This indicates the presence of significant heteroskedasticity in the data. Similar results are observed for both weekly and monthly return series. As a result, robust standard errors, specifically White's heteroskedasticity-consistent standard errors, are employed in the subsequent analysis to enhance the reliability of the inference.

The same table also reports the results of the autocorrelation test. The Durbin-Watson statistics are close to 2, suggesting no significant autocorrelation in the residuals. This supports the assumption that the residuals are approximately independent and randomly distributed.

Table 6. Heteroskedasticity and autocorrelation test results.

Variable	Breusch-Pagan p-value	White p-value	Durbin-Watson
Model 1	0.241830	1.39×10^{-9}	2.462123
Model 2	0.399727	1.42×10^{-6}	2.463516
Model 3	0.280230	1.09×10^{-8}	2.462779
Model 4	0.352705	2.81×10^{-7}	2.463716
AC EMEA	0.145419	4.66×10^{-7}	2.394853
AC America	0.002367	1.08×10^{-32}	2.258335
AC APAC	0.000006	3.27×10^{-52}	2.340162
AC WI	0.015467	7.81×10^{-26}	2.387793

5.3 Model performance based on monthly returns

Although using monthly performance data would be ideal for analyzing the extent to which regional index models explain Euro Stoxx 50 returns, due to the typically lower noise in monthly compared to daily returns, the limited sample size poses a constraint. With only 54 monthly observations available, the dataset is insufficient to support reliable conclusions for the entire analysis. Therefore, this paper also incorporates weekly and daily return frequencies to enhance the robustness of the results. Given these data

limitations, the analysis covers the period from the beginning of July 2019 to the end of 2023.

According to table 7, the MSCI AC America index outperformed the other indexes during the sample period in terms of risk-adjusted returns. While the Euro Stoxx 50 exhibited a moderate annual return relative to the other indexes, it also experienced the highest annualized standard deviation during the same period.

Table 7. Annualized descriptive statistics for monthly returns.

Series	Observations	Annual Return (%)	Annual Std Dev (%)	Risk-Adjusted Return	Max Drawdown (%)
SX5E	54	5.86	19.53	0.30	-27.25
Model_1	54	5.67	15.10	0.38	-22.65
Model_2	54	5.36	15.16	0.35	-22.98
Model_3	54	5.59	15.11	0.37	-22.74
Model_4	54	5.44	15.15	0.36	-22.90
AC_EMEA	54	4.01	16.51	0.24	-25.46
AC_America	54	10.93	17.14	0.64	-21.75
AC_APAC	54	1.92	13.92	0.14	-22.35
AC_WI	54	7.96	15.59	0.51	-21.68

Table 8 presents the OLS regression results for each dependent variable estimated separately, illustrating the extent to which each factor explains the performance of the Euro Stoxx 50. The most noticable insights are reflected in the beta coefficients and R-squared values. Among the tested indexes, the MSCI AC Europe and Middle East index demonstrated the highest explanatory power, with an R-squared value exceeding 0.94.

Although the models constructed according to the methodology section exhibited slightly lower explanatory accuracy, they still achieved strong R-squared values above 0.85. This performance surpasses that of all other MSCI indexes in the sample, except for the Europe and Middle East index. Furthermore, these custom models produced the steepest slopes, with beta coefficients approaching 1.2, suggesting that a 1% change in Euro Stoxx 50 returns corresponds to an approximate 1.2% change in the model-predicted returns. Notably, the MSCI AC America index was the only index with a beta coefficient below 1

during the sample period, indicating a comparatively muted sensitivity to changes in Euro Stoxx 50 returns.

Table 8. Regression results for monthly returns: SX5E vs. factors.

Factor	Intercept	Beta	StdErr(Beta)	t(Beta)	R^2
Model_1	-0.0008	1.1934***	0.0847	14.0824	0.8520
Model_2	-0.0005	1.1999***	0.0791	15.1640	0.8676
Model_3	-0.0007	1.1953***	0.0834	14.3310	0.8558
Model_4	-0.0005	1.1984***	0.0804	14.9004	0.8641
AC_{EMEA}	0.0010	1.1469***	0.0408	28.0960	0.9407
$\text{AC}_{America}$	-0.0035	0.9249***	0.1123	8.2329	0.6587
AC_{APAC}	0.0032	1.0235***	0.1542	6.6370	0.5326
AC_{WI}	-0.0024	1.0927***	0.1038	10.5287	0.7607

Notes: t-statistics in parentheses. *p<0.10, **p<0.05, ***p<0.01. Each regression estimated separately by OLS.

The correlation analysis also yielded noteworthy results. The correlation matrix in table 9 illustrates the degree of association among the indexes and models. As expected, the Euro Stoxx 50 exhibited the highest correlation with the MSCI AC Europe and Middle East index, followed by the constructed models. However, the table also reveals that the models demonstrate significantly stronger correlations with other global indexes compared to the Europe and Middle East index. For example, the model-based indexes exhibited correlations close to 0.99 with the MSCI World Index.

Furthermore, the correlation between the constructed models was nearly perfect, indicating that the proportional weighting of revenues from the “rest of the world” and “other” categories, whether multiplied by MSCI EMEA returns or MSCI World Index returns, does not materially affect the final outcomes.

Table 9. Correlation matrix for monthly returns.

	SX5E	$Model_1$	$Model_2$	$Model_3$	$Model_4$	AC_{EMEA}	$AC_{America}$	AC_{APAC}	AC_{WI}
SX5E	1.000	0.923	0.931	0.925	0.930	0.970	0.812	0.730	0.872
$Model_1$	0.923	1.000	1.000	1.000	1.000	0.965	0.947	0.856	0.987
$Model_2$	0.931	1.000	1.000	1.000	1.000	0.972	0.939	0.853	0.982
$Model_3$	0.925	1.000	1.000	1.000	1.000	0.967	0.945	0.855	0.986
$Model_4$	0.930	1.000	1.000	1.000	1.000	0.970	0.941	0.853	0.983
AC_{EMEA}	0.970	0.965	0.972	0.967	0.970	1.000	0.866	0.762	0.921
$AC_{America}$	0.812	0.947	0.939	0.945	0.941	0.866	1.000	0.734	0.985
AC_{APAC}	0.730	0.856	0.853	0.855	0.853	0.762	0.734	1.000	0.821
AC_{WI}	0.872	0.987	0.982	0.986	0.983	0.921	0.985	0.821	1.000

The analysis of actual Euro Stoxx 50 returns and the model-predicted returns reveals broadly similar fluctuations over the sample period, as illustrated in figure 6. The America and Asia-Pacific indexes appeared to fluctuate with a certain delay or experienced different market shocks compared to the Euro Stoxx 50. In contrast, the remaining indexes exhibited more synchronized shocks throughout the period, an observation that is consistent with the results from the correlation matrix in table 9.

Further insights are provided by the regression analysis conducted for each dependent variable, shown in figure 7, where the predicted monthly returns are compared to the actual values. These charts offer a clear visual representation of how closely the observations align with the OLS regression lines and associated beta values. Notably, data points corresponding to exceptionally high returns tend to deviate more from the regression line, suggesting that extreme returns are inherently more difficult to predict accurately.

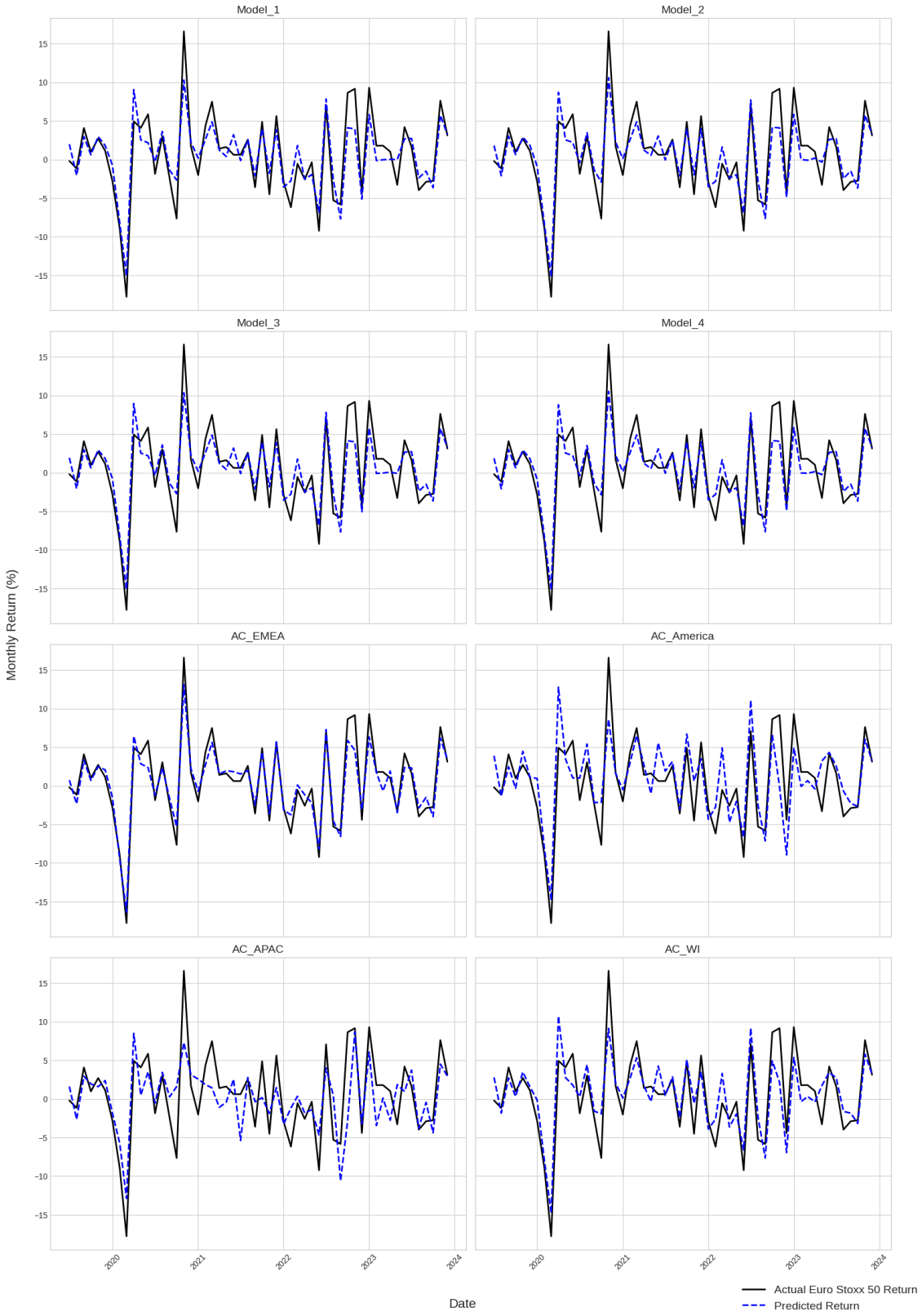

Figure 6. Euro Stoxx 50, models and MSCI indexes performance for monthly returns.

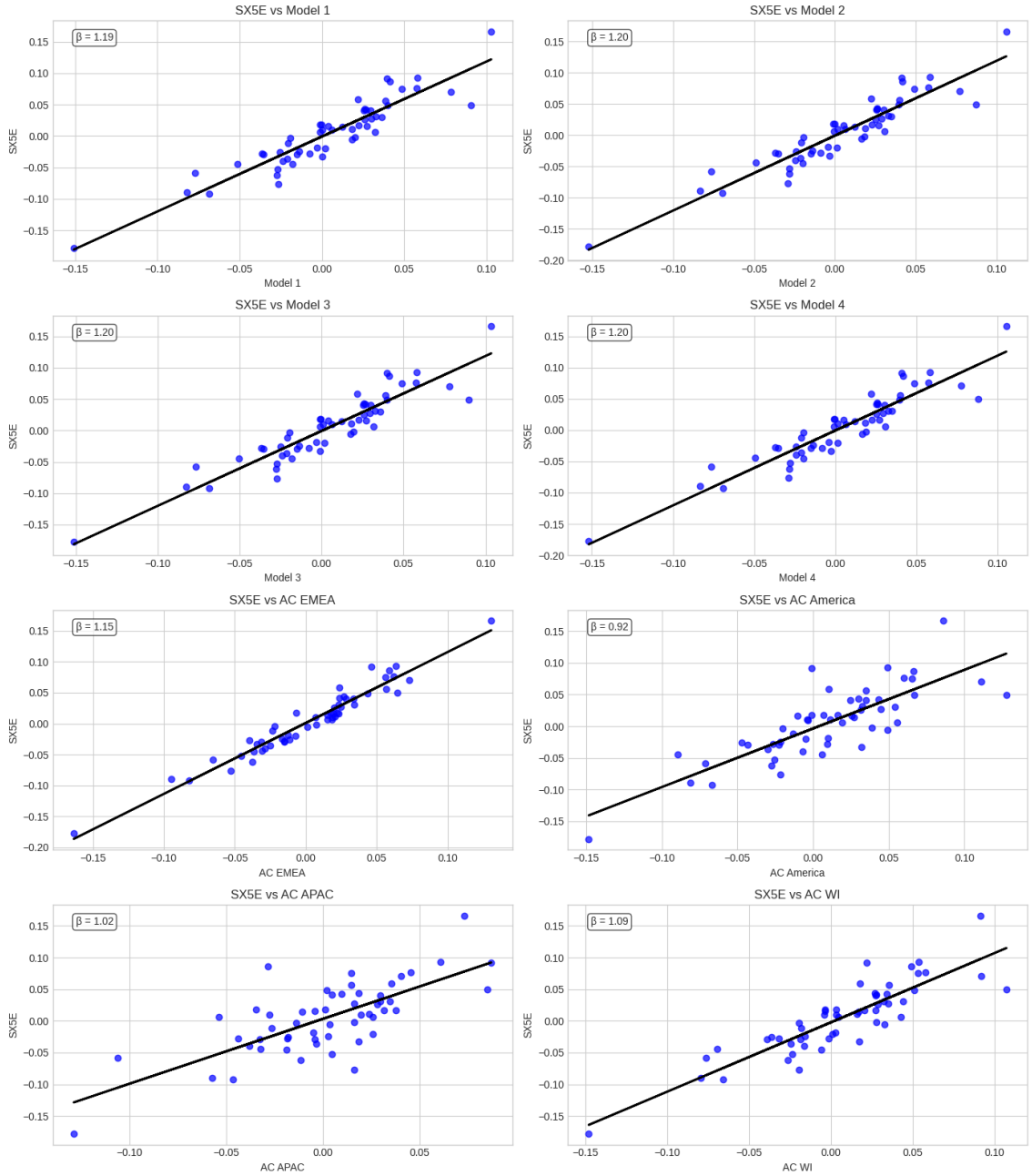

Figure 7. Monthly returns with OLS fit.

5.4 Model performance based on weekly returns

A similar analysis was conducted using weekly returns; however, due to the higher frequency and associated noise, the results differed from those based on monthly data. As shown in table 10, the number of observations increased, and the maximum drawdowns

(in percentage terms) decreased as a result of the higher frequency. Table 11 further indicates that the explanatory power, as measured by the R-squared values, declined across all indexes.

Despite this reduction, the models achieved R-squared values close to 0.8, which remains relatively high for capturing the dynamics of Euro Stoxx 50 returns. Nevertheless, their explanatory power did not surpass that of the MSCI AC Europe and Middle East index, which continued to exhibit the strongest performance in this regard.

Table 10. Annualized descriptive statistics for weekly returns.

Series	Observations	Annual Return (%)	Annual Std Dev (%)	Risk-Adjusted Return	Max Drawdown (%)
SX5E	236	5.81	22.57	0.26	-36.22
Model_1	236	5.62	16.29	0.35	-32.03
Model_2	236	5.32	16.44	0.32	-32.20
Model_3	236	5.54	16.32	0.34	-32.07
Model_4	236	5.40	16.40	0.33	-32.16
AC_EMEA	236	3.95	18.88	0.21	-34.21
AC_America	236	10.67	18.61	0.57	-33.51
AC_APAC	236	1.64	15.65	0.11	-26.25
AC_WI	236	7.73	16.63	0.46	-32.09

Table 11. Regression results for weekly returns: SX5E vs factors.

Factor	Intercept	Beta	StdErr(Beta)	t(Beta)	R^2
Model_1	-0.000	1.227***	0.076	16.250	0.784
Model_2	-0.000	1.237***	0.064	19.384	0.812
Model_3	-0.000	1.230***	0.072	16.977	0.791
Model_4	-0.000	1.235***	0.067	18.522	0.805
$\text{MSCI}_{Europe\&ME}$	0.000	1.155***	0.038	30.608	0.933
$\text{MSCI}_{AMERICA}$	-0.001	0.809***	0.125	6.491	0.445
MSCI_{APAC}	0.001	0.940***	0.145	6.482	0.425
MSCI_{ACWI}	-0.001	1.067***	0.120	8.862	0.618

Notes: t-statistics in parentheses. *p<0.10, **p<0.05, ***p<0.01. Each regression estimated separately by OLS.

Interestingly, the correlation matrix in table 12 reveals notable patterns. Once again, the constructed models showed a stronger correlation with the MSCI World Index than did either the Euro Stoxx 50 or the MSCI AC Europe and Middle East index. While the models also maintained a strong correlation with the Euro Stoxx 50 index, it remained slightly lower than the correlation observed with the MSCI Europe and Middle East index. Additionally, the MSCI APAC index consistently exhibited the lowest correlations with other indexes, suggesting that stock market performance in the Asia-Pacific region is less integrated with the movements of other regional markets during the sample period.

Table 12. Correlation matrix for weekly returns.

	SX5E	$Model_1$	$Model_2$	$Model_3$	$Model_4$	AC_{EMEA}	$AC_{America}$	AC_{APAC}	AC_{WI}
SX5E	1.000	0.885	0.901	0.889	0.897	0.966	0.667	0.652	0.786
$Model_1$	0.885	1.000	0.999	1.000	0.999	0.935	0.891	0.840	0.971
$Model_2$	0.901	0.999	1.000	0.999	1.000	0.950	0.872	0.835	0.960
$Model_3$	0.889	1.000	0.999	1.000	1.000	0.939	0.886	0.839	0.968
$Model_4$	0.897	0.999	1.000	1.000	1.000	0.947	0.876	0.836	0.963
AC_{EMEA}	0.966	0.935	0.950	0.939	0.947	1.000	0.713	0.718	0.838
$AC_{America}$	0.667	0.891	0.872	0.886	0.876	0.713	1.000	0.661	0.972
AC_{APAC}	0.652	0.840	0.835	0.839	0.836	0.718	0.661	1.000	0.791
AC_{WI}	0.786	0.971	0.960	0.968	0.963	0.838	0.972	0.791	1.000

Similar to monthly returns, weekly returns also exhibit comparable OLS models, as shown in figure 9, with only slightly different beta values due to the increased frequency over the same time period. Figure 8 likewise displays similar fluctuations between the lines; however, the higher frequency introduces greater delays and noise, particularly in indexes that exhibit weaker correlations with the Euro Stoxx 50 weekly returns.

The models, along with the Europe and Middle East index, tracked actual returns and volatility reasonably well, except during two major shocks in early 2020 and early 2022, corresponding to the COVID-19 pandemic and Russia's full-scale invasion of Ukraine. The Euro Stoxx 50 returns were most volatile during these periods, and none of the models fully captured the magnitude of the movements.

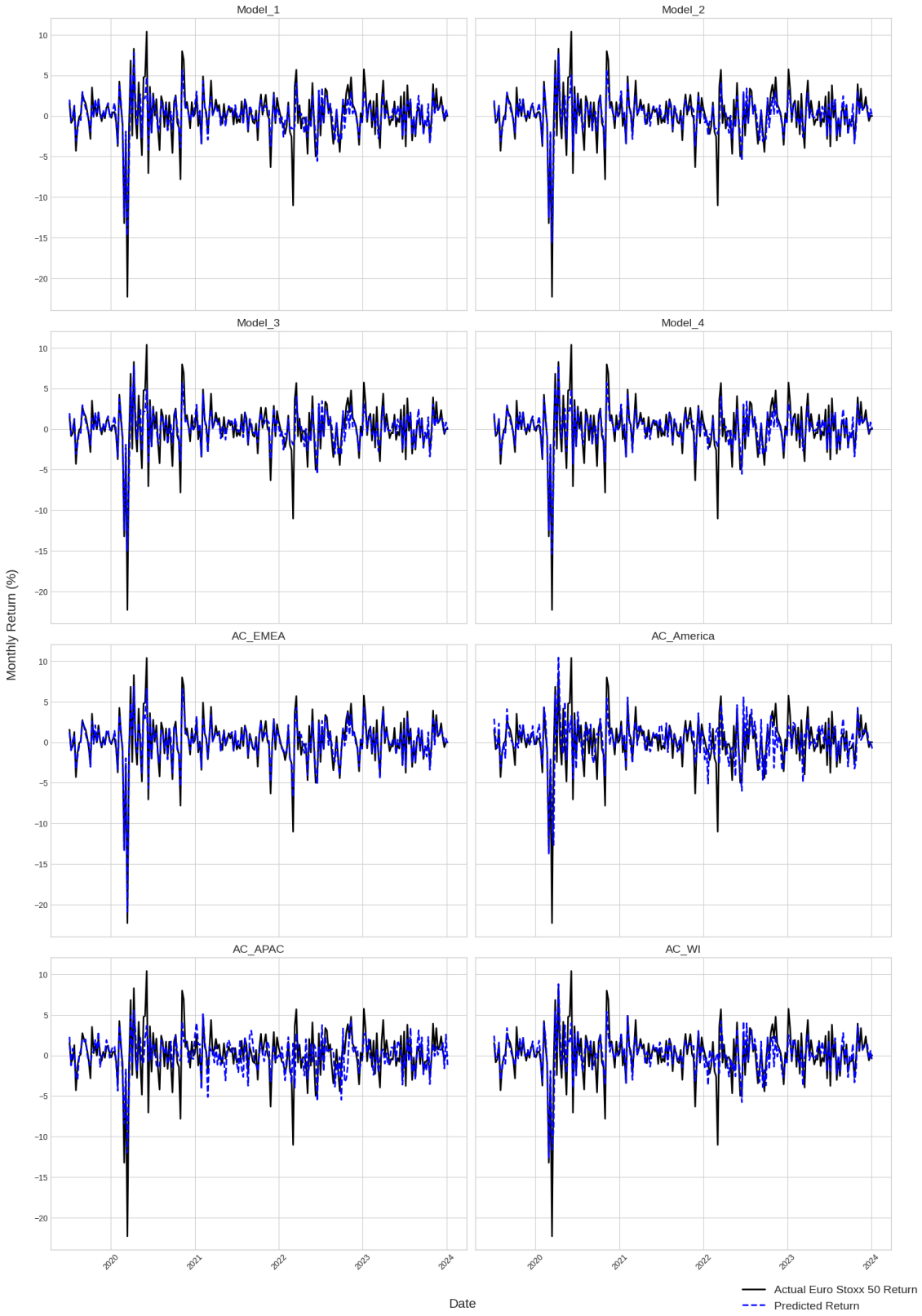

Figure 8. Euro Stoxx 50, models and MSCI indexes performance for weekly returns.

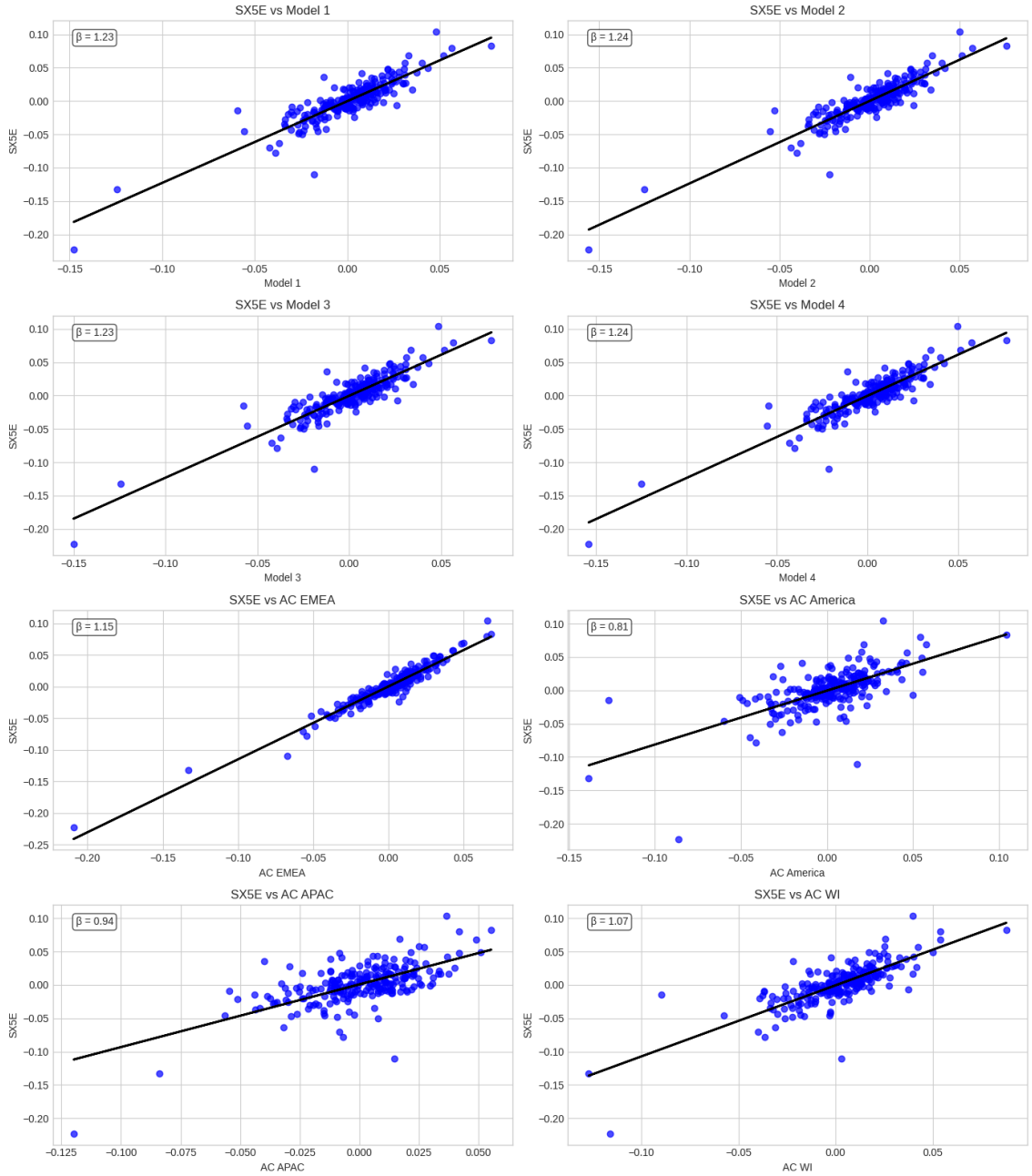

Figure 9. Weekly returns with OLS model fit.

5.5 Model performance based on daily returns

Lastly, daily returns were also employed for the same period to increase the number of observations, thereby aiming to produce more reliable results, evident from table 13. This yielded a total of 1,157 observations for the specified timeframe. However, the higher fre-

quency also introduced greater noise and lag between different stock markets. This effect is perhaps reflected in the R-squared values presented in table 14, where model values are close to 0.7, which is a notable decrease compared to those derived from monthly returns. Consequently, model performance remained only moderately effective in predicting Euro Stoxx 50 returns on a daily basis. Additionally, the R-squared value for the MSCI EMEA index was approximately 0.88, which, although higher than the other model values, no longer indicates particularly strong explanatory power. Furthermore, the beta coefficients for the MSCI America and MSCI APAC indexes became unreliable, with values falling below 0.6 relative to the Euro Stoxx 50.

Table 13. Annualized descriptive statistics for daily returns.

Series	Observations	Annual Return (%)	Annual Std Dev (%)	Risk-Adjusted Return	Max Drawdown (%)
SX5E	1157	5.59	21.53	0.26	-39.58
Model_1	1157	5.28	15.76	0.33	-34.45
Model_2	1157	4.98	15.79	0.32	-34.56
Model_3	1157	5.20	15.76	0.33	-34.47
Model_4	1157	5.06	15.78	0.32	-34.53
AC_EMEA	1157	3.72	18.59	0.20	-37.12
AC_America	1157	10.40	21.67	0.48	-36.99
AC_APAC	1157	1.52	15.74	0.10	-28.58
AC_WI	1157	7.50	17.19	0.44	-34.87

Table 14. Regression results for daily returns: SX5E vs. factors.

Factor	Intercept	Beta	StdErr(Beta)	t(Beta)	R^2
Model_1	-0.0000	1.1403***	0.0420	27.1374	0.6964
Model_2	-0.0000	1.1666***	0.0366	31.8380	0.7323
Model_3	-0.0000	1.1475***	0.0406	28.2573	0.7055
Model_4	-0.0000	1.1608***	0.0380	30.5695	0.7239
AC_{EMEA}	0.0001	1.0861***	0.0187	58.2285	0.8794
$\text{AC}_{America}$	-0.0000	0.5731***	0.0563	10.1824	0.3328
AC_{APAC}	0.0002	0.5282***	0.0759	6.9564	0.1492
AC_{WI}	-0.0000	0.8856***	0.0588	15.0640	0.5001

Notes: All coefficients are significant at the 1% level (***p$<$0.01). Each regression estimated separately by OLS.

Despite being designed to replicate the SX5E index, the models still exhibited strong correlations with the MSCI AC WI, as shown in table 15. Notably, MSCI AC America displayed a slightly higher direct correlation with MSCI AC WI (0.964) compared to the models, whose correlations ranged from 0.935 to 0.952. However, AC America demonstrated significantly lower correlations with other regional indexes, particularly with AC APAC, which had a correlation of just 0.336, indicating a degree of regional isolation.

In contrast, the models displayed more balanced global correlations. Although their correlation with MSCI WI was marginally lower than that of MSCI America, they considerably outperformed in cross-regional relationships. For example, the correlation between the models and MSCI APAC was approximately 0.64, nearly twice that between MSCI America and MSCI APAC. This suggests that, while the models may slightly sacrifice alignment with a single region's connection to MSCI WI, they gain in broader global representativeness and interregional connectivity.

In summary, when a model's correlation with a specific regional index (e.g., AC America) was lower than that region's correlation with the MSCI World Index, it often compensated through stronger correlations with other regional indexes, thereby contributing to a more globally cohesive return profile. A similar pattern is observed in the case of the Euro Stoxx 50, where all models exhibit slightly lower correlations compared to the MSCI EMEA index, yet demonstrate significantly stronger correlations with other MSCI regional and global indexes.

Table 15. Correlation matrix for daily returns.

	SX5E	$Model_1$	$Model_2$	$Model_3$	$Model_4$	AC_{EMEA}	$AC_{America}$	AC_{APAC}	AC_{WI}
SX5E	1.000	0.835	0.856	0.840	0.851	0.938	0.577	0.386	0.707
$Model_1$	0.835	1.000	0.998	1.000	0.999	0.897	0.844	0.642	0.952
$Model_2$	0.856	0.998	1.000	0.999	1.000	0.920	0.816	0.640	0.935
$Model_3$	0.840	1.000	0.999	1.000	1.000	0.903	0.837	0.642	0.948
$Model_4$	0.851	0.999	1.000	1.000	1.000	0.915	0.823	0.641	0.939
AC_{EMEA}	0.938	0.897	0.920	0.903	0.915	1.000	0.588	0.493	0.744
$AC_{America}$	0.577	0.844	0.816	0.837	0.823	0.588	1.000	0.336	0.964
AC_{APAC}	0.386	0.642	0.640	0.642	0.641	0.493	0.336	1.000	0.531
AC_{WI}	0.707	0.952	0.935	0.948	0.939	0.744	0.964	0.531	1.000

Due to the increased frequency, figure 10 became more challenging to interpret. However, the general idea remains: the less the actual Euro Stoxx 50 return lines overlap with the predicted returns (blue line), the better the model's explanatory power. Once again, the MSCI AC EMEA index demonstrated the strongest comovement, while MSCI AC APAC exhibited the weakest. These findings are more intuitively conveyed in the regression plots shown in figure 11. The models and the MSCI AC EMEA index produced observed returns that were most closely aligned with Euro Stoxx 50 returns throughout the sample period. Additionally, few data points deviated substantially from the regression line, indicating relatively low residual error. In contrast, the other MSCI regional indexes showed significantly larger error terms, reflecting weaker alignment with the Euro Stoxx 50 on a

daily basis (see appendix table 14).

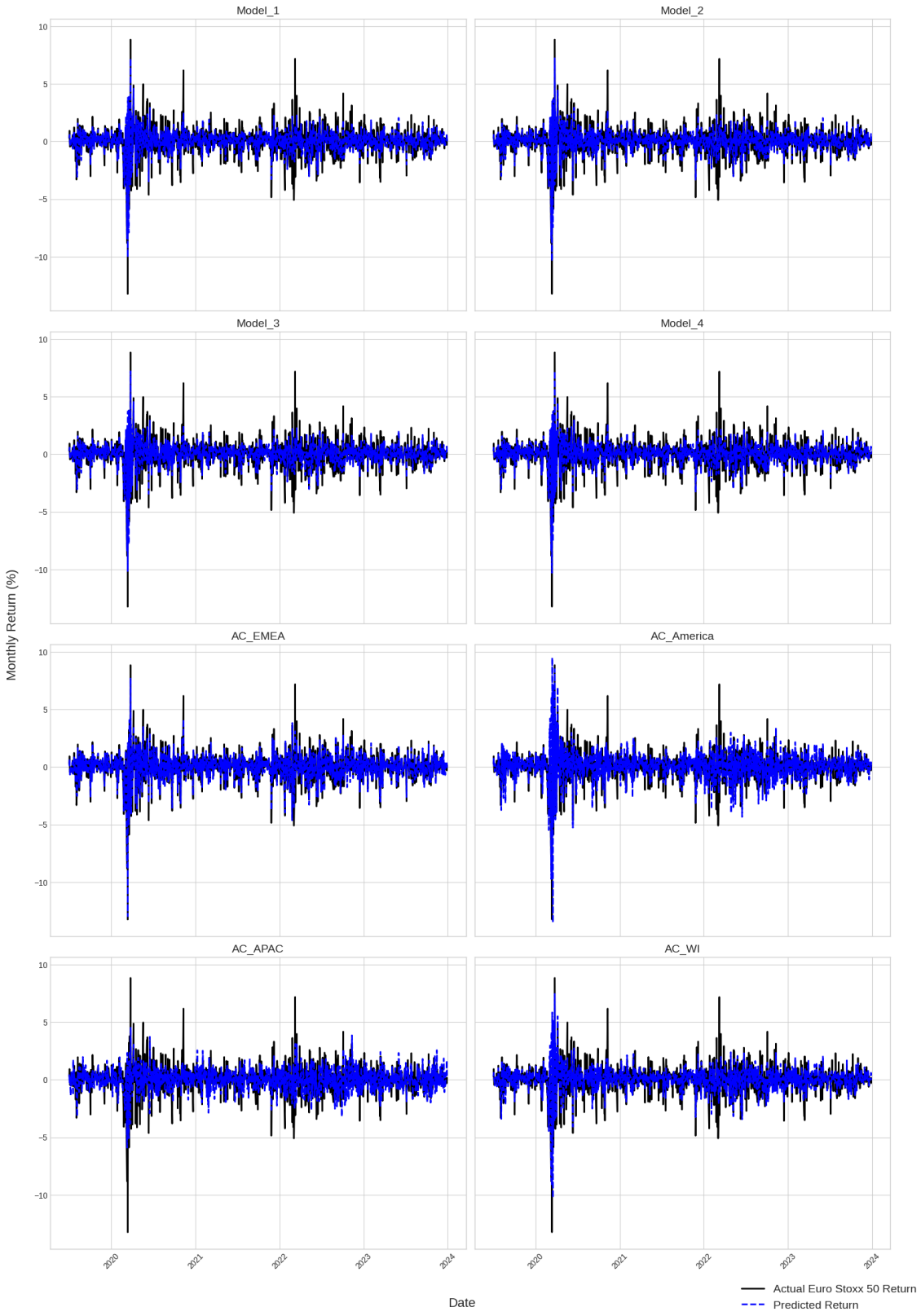

Figure 10. Euro Stoxx 50, models and MSCI indexes performance for daily returns.

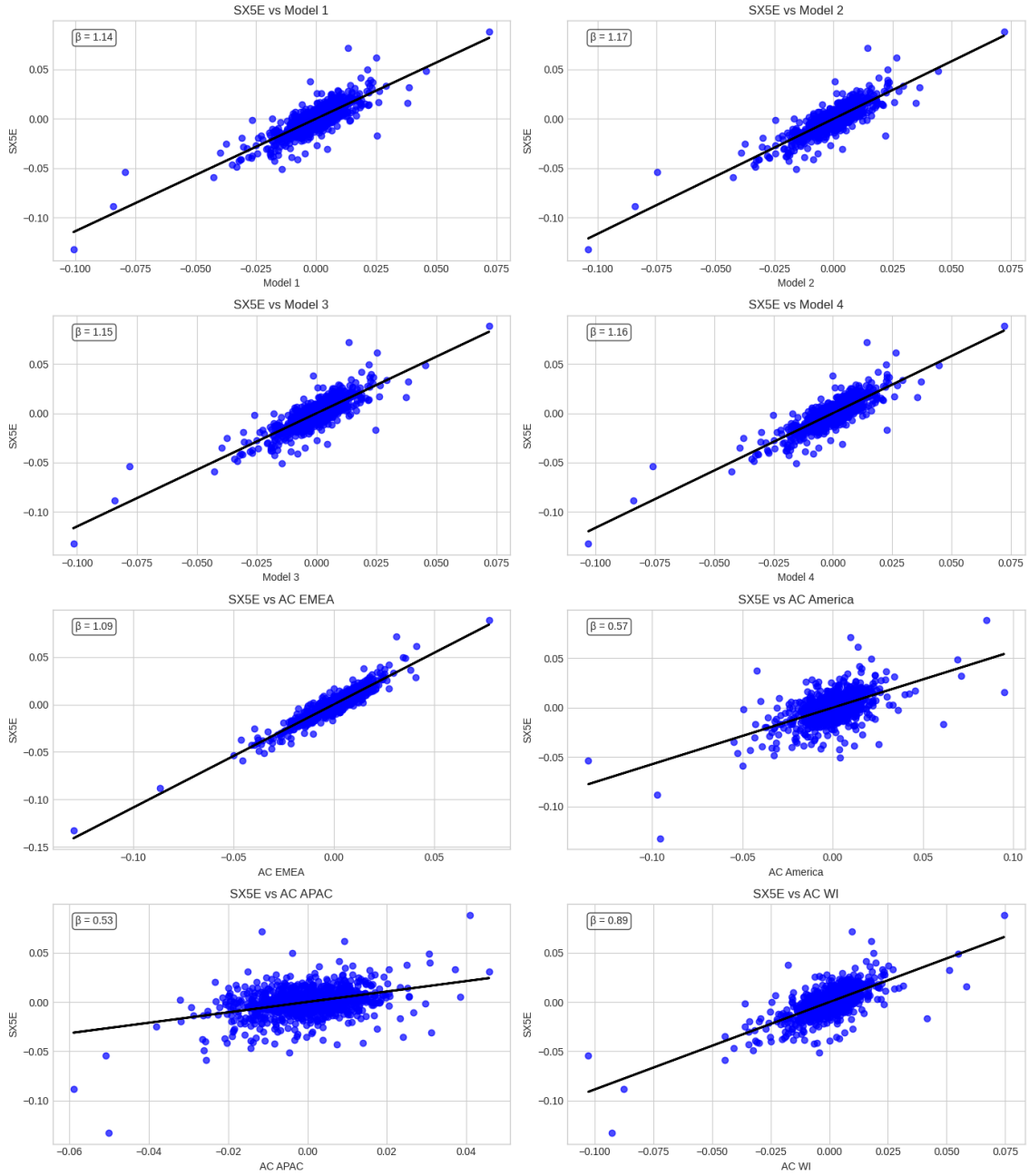

Figure 11. OLS model fit for daily returns.

5.6 Results summary

Based on the analysis conducted using monthly, weekly, and daily returns across various models, it was observed that monthly returns, due to their lower noise levels, provided the strongest explanatory power in predicting Euro Stoxx 50 performance. Nevertheless,

daily and weekly returns were utilized to increase the number of observations, addressing data limitations related to the availability of constituent weightings over time. Consequently, the first hypothesis can be both supported and challenged depending on the return frequency used. For daily returns, the models were relatively weak in predicting Euro Stoxx 50 performance, while for monthly returns they proved more effective, with weekly returns yielding results somewhere in between.

The analysis also revealed that although the constructed models explained Euro Stoxx 50 returns reasonably well, they did not outperform the MSCI Europe and Middle East index as an explanatory tool. This can be partially attributed to the fact that this MSCI index includes many of the same large, liquid constituents as the Euro Stoxx 50, given their significant market presence. Additionally, a potential home bias among investors may play a role: market participants may place disproportionate emphasis on domestically headquartered firms without fully accounting for their global revenue exposures. This behavior could contribute to the stronger alignment observed between the MSCI Europe and Middle East index and Euro Stoxx 50 returns.

Given the expectation that the models would outperform any single MSCI index in explaining Euro Stoxx 50 returns, the second hypothesis must be rejected. The MSCI Europe and Middle East index consistently provided superior explanatory power across all return frequencies.

However, the third hypothesis is supported. When evaluating the models not only by their ability to explain Euro Stoxx 50 returns but also by their capacity to capture broader global market comovements, they demonstrate a clear improvement in alignment with other equity indexes, particularly the MSCI AC WI. These models are more effective at explaining the interconnected behavior between regional and global equity markets. This highlights their value in providing a more globally integrated perspective that can be effectively used to understand cross-market dynamics.

5.7 Limitations

As previously discussed, this study faced several limitations. The sample period was restricted to fewer than five years due to the high cost of data subscriptions and limited access to historical index weightings. Data collection was further hindered by paywalls and the absence of structured, standardized geographic revenue disclosures among MNCs, making the process labor-intensive and time-consuming. Although quarterly revenue data were initially considered, inconsistencies with annual reports necessitated a focus on annual disclosures.

Because companies do not report regional revenues in a standardized format, several approximations were necessary, which may have slightly affected the accuracy of the final results. These included normalizing weights by excluding firms that did not disclose regional revenue exposures and assuming their revenue distributions resembled those of the average firm in the Euro Stoxx 50. As a result, this introduces a selection bias, as the actual regional revenue distributions of the excluded firms are unknown. Nevertheless, the total weight of these companies during the sample period was below 5%, which helps maintain the overall accuracy of the analysis. The lack of standardization also necessitated the use of broad regional groupings rather than country-specific data. While still informative, this approach introduces additional complexity, as MSCI indexes span multiple countries with varying levels of representation.

A further constraint was the use of MSCI regional indexes as proxies for domestic economic exposure. This method assumed that indexes derive all revenues from their respective regions, which is an oversimplification, given that many MSCI constituents are large multinationals with substantial non-domestic revenue. This created a “revenue loop” issue, whereby index performance may not align with actual regional economic conditions. Constructing more accurate domestic indexes was not feasible due to the lack of data on constituents’ actual revenue exposures and weightings. This data, if available, would have enabled more precise methodologies, as demonstrated in prior studies

such as Dumas et al. (2023).

Despite these limitations, the study offers new insights into how equity indexes may be priced based on constituent weights, regional revenue exposures, and the performance of regional equity markets. Future research with longer timeframes and more granular data could produce more robust results and further illuminate the behavior of MSCI index revenue exposures and global equity pricing.

6 Conclusions

This research paper, initially inspired by the works of Diermeier and Solnik (2001) and Dumas et al. (2023), addresses a timely topic amid growing uncertainty in global equity markets. In an environment characterized by geopolitical tensions, trade barriers, and region-specific shocks, investors must better understand how MNCs generate revenues across regions for effective risk management. Periods of geopolitical instability historically coincide with increased demand for international portfolio management, highlighting the relevance of this research.

Despite the increasing globalization of firms, there is still limited academic literature on how the equity valuation of MNCs should account for the geographic distribution of their revenues. This paper contributes to the literature by offering a framework for evaluating the Euro Stoxx 50 index based on its constituents' regional revenue exposures and the performance of corresponding regional equity indexes. The findings indicate that when revenue weights and regional index performance are incorporated, the resulting models improve overall correlation with global indexes, particularly the MSCI AC WI. While this approach may slightly reduce explanatory power in the firms' domestic regions, it substantially enhances interregional alignment and global representativeness.

In summary, the models provided strong explanatory power for Euro Stoxx 50 monthly returns but were less effective at capturing daily return movements due to increased frequency, market lags, and noise. These observations suggest that future research using monthly data over a longer time horizon could yield more robust insights. There is also a small risk of overfitting, as the models' methodology involved approximations to some extent. Nevertheless, these risks are quite insignificant, as the weights of these approximations are below 5% of the constituents' total weights, keeping the models accurate.

Future research could analyze an index with a larger set of constituents and incorporate industry-specific effects, as some sectors may be more vulnerable to regional revenue

shocks. This study did not explore such dynamics due to the limited number of constituents in the Euro Stoxx 50, which made industry-level analysis impractical. Future studies could also improve model accuracy by excluding overlapping constituents from the descriptive index, thereby eliminating duality and enhancing the index's representativeness. Additionally, addressing the "revenue loop" issue would further strengthen the robustness of the findings.

Nevertheless, this research underscores the importance of looking beyond the geographic listing of an index to assess the true economic exposure of its constituents. Since different regions are associated with distinct risk premia, understanding the regional distribution of revenue flows is essential for accurate valuation. This approach improves our understanding of how the index and its proportional returns co-move with other regional markets.

Finally, the revenue-weighted models constructed in this paper exhibited beta values approximately 20% higher than 1.0, indicating that a 1% change in Euro Stoxx 50 revenues corresponds to a 1.2% change in model performance. This deviation may reflect a home bias, whereby Euro Stoxx 50 companies are priced more favorably than their global revenue distribution would suggest. Similarly, the American index showed a beta below 1, potentially helping explain why some European firms pursue cross-listing in the U.S. to benefit from increased liquidity and global visibility Pagano, Röell, and Zechner (2002).

Overall, this research offers a new perspective on how the performance of the Euro Stoxx 50 can be interpreted through the lens of regional revenue exposure, suggesting that revenues from certain regions may be priced higher than others. This supports the notion that home bias tends to persist and that its extent in equity index pricing could be better understood through similar regression model testing as applied in this study.

Bibliography

Adler, M., & Solnik, B. H. (1974, May). Session Topic: Capital Asset Pricing Models in an International Context: THE INTERNATIONAL PRICING OF RISK: AN EMPIRICAL INVESTIGATION OF THE WORLD CAPITAL MARKET STRUCTURE. *The Journal of Finance*, *29*(2), 365–378. https://doi.org/10.1111/j.1540-6261.1974.tb03051.x

Agmon, T. (1973, January). Country Risk: The Significance of the Country Factor for Share-Price Movements in the United Kingdom, Germany, and Japan. *The Journal of Business*, *46*(1), 24. https://doi.org/10.1086/295505

Asness, C. S., Moskowitz, T. J., & Pedersen, L. H. (2013, June). Value and Momentum Everywhere. *The Journal of Finance*, *68*(3), 929–985. https://doi.org/10.1111/jofi.12021

Bae, J. W., Elkamhi, R., & Simutin, M. (2019, October). The Best of Both Worlds: Accessing Emerging Economies via Developed Markets. *The Journal of Finance*, *74*(5), 2579–2617. https://doi.org/10.1111/jofi.12817

Baillie, R. T., & Cho, D. (2016, December). Assessing Euro crises from a time varying international CAPM approach. *Journal of Empirical Finance*, *39*, 197–208. https://doi.org/10.1016/j.jempfin.2016.03.005

Baker, S. R., Bloom, N., & Davis, S. J. (2016, November). Measuring Economic Policy Uncertainty*. *The Quarterly Journal of Economics*, *131*(4), 1593–1636. https://doi.org/10.1093/qje/qjw024

Barone, R. N. (1983, May). RISK AND INTERNATIONAL DIVERSIFICATION: ANOTHER LOOK. *Financial Review*, *18*(2), 184–195. https://doi.org/10.1111/j.1540-6288.1983.tb00145.x

Bekaert, G., Harvey, C. R., Lundblad, C. T., & Siegel, S. (2013, September). The European Union, the Euro, and equity market integration. *Journal of Financial Economics*, *109*(3), 583–603. https://doi.org/10.1016/j.jfineco.2013.03.008

Bruner, R. F., Li, W., Kritzman, M., Myrgren, S., & Page, S. (2008, June). Market integration in developed and emerging markets: Evidence from the CAPM. *Emerging Markets Review*, *9*(2), 89–103. https://doi.org/10.1016/j.ememar.2008.02.002

Caldara, D., & Iacoviello, M. (2022, April). Measuring Geopolitical Risk. *American Economic Review*, *112*(4), 1194–1225. https://doi.org/10.1257/aer.20191823

Carhart, M. M. (1997, March). On Persistence in Mutual Fund Performance. *The Journal of Finance*, *52*(1), 57–82. https://doi.org/10.1111/j.1540-6261.1997.tb03808.x

Clyman, D. R. (1997, January). International arbitrage pricing theory: Relating risk premia. *International Review of Financial Analysis*, *6*(1), 13–20. https://doi.org/10.1016/S1057-5219(97)90016-8

Damodaran, A. (2012). *Investment valuation: Tools and techniques for determining the value of any asset*. Germany: Wiley.

De Santis, G., & Gerard, B. (1997, December). International Asset Pricing and Portfolio Diversification with Time-Varying Risk. *The Journal of Finance*, *52*(5), 1881–1912. https://doi.org/10.1111/j.1540-6261.1997.tb02745.x

Deutsche Börse Group. (2023). *Replacements for linde in dax and stoxx indices announced*. (News) Retrieved from https://www.deutsche-boerse.com/dbg-en/media/news-stories/press-releases/Replacements-for-Linde-in-DAX-and-STOXX-indices-announced-3405722

Deutsche Börse Group. (2024a). *Stoxx index methodology guide*. (Stoxx's Official White Paper) Retrieved from https://www.stoxx.com/methodology_guide.pdf

Deutsche Börse Group. (2024b). *Stoxx® calculation guide*. (Stoxx's Official White Paper) Retrieved from https://www.stoxx.com/document/Indices/Common/Indexguide/stoxx_calculation_guide.pdf

Diermeier, J., & Solnik, B. (2001, July). Global Pricing of Equity. *Financial Analysts Journal*, *57*(4), 37–47. https://doi.org/10.2469/faj.v57.n4.2464

Do, H. X., Nguyen, N. H., & Nguyen, Q. M. (2022, May). Multinationals and stock return comovement. *Global Finance Journal*, *52*, 100714. https://doi.org/10.1016/j.gfj.2022.100714

Dumas, B., Gabuniya, T., & Marston, R. C. (2022, April). Firms' exposures to geographic risks. *Journal of International Money and Finance*, *122*, 102549. https://doi.org/10.1016/j.jimonfin.2021.102549

Dumas, B., Gabuniya, T., & Marston, R. C. (2023, July). Geographic Investing: Stock Return Indexes Based on Company Operations. *Financial Analysts Journal*, *79*(3), 64–74.

https://doi.org/10.1080/0015198X.2023.2189891

Dumas, B., & Solnik, B. (1995, June). The World Price of Foreign Exchange Risk. *The Journal of Finance*, *50*(2), 445–479. https://doi.org/10.1111/j.1540-6261.1995.tb04791.x

Elbannan, M. A. (2014, December). The Capital Asset Pricing Model: An Overview of the Theory. *International Journal of Economics and Finance*, *7*(1), p216. https://doi.org/10.5539/ijef.v7n1p216

Engel, C., & Rodrigues, A. P. (1989). Tests of international capm with time-varying covariances. *Journal of Applied Econometrics*, *4*(2), 119–138. http://www.jstor.org/stable/2096465.

Fama, E. F., & French, K. R. (1992, June). The Cross-Section of Expected Stock Returns. *The Journal of Finance*, *47*(2), 427–465. https://doi.org/10.1111/j.1540-6261.1992.tb04398.x

Fama, E. F., & French, K. R. (1993, February). Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics*, *33*(1), 3–56. https://doi.org/10.1016/0304-405X(93)90023-5

Fama, E. F., & French, K. R. (2004, September). The capital asset pricing model: Theory and evidence. *Journal of Economic Perspectives*, *18*(3), 25–46. https://doi.org/10.1257/0895330042162430

Fama, E. F., & French, K. R. (2012, September). Size, value, and momentum in international stock returns. *Journal of Financial Economics*, *105*(3), 457–472. https://doi.org/10.1016/j.jfineco.2012.05.011

Ferson, W. E., & Harvey, C. R. (1991). The variation of economic risk premiums. *Journal of Political Economy*, *99*(2), 385–415. http://www.jstor.org/stable/2937686.

Fillat, J. L., & Garetto, S. (2015, November). Risk, Returns, and Multinational Production*. *The Quarterly Journal of Economics*, *130*(4), 2027–2073. https://doi.org/10.1093/qje/qjv031

Fillat, J. L., Garetto, S., & Oldenski, L. (2015, May). Diversification, cost structure, and the risk premium of multinational corporations. *Journal of International Economics*, *96*(1), 37–54. https://doi.org/10.1016/j.jinteco.2015.01.004

French, K. R., & Poterba, J. M. (1991). Investor diversification and international equity markets. *The American Economic Review*, *81*(2), 222–226.

http://www.jstor.org/stable/2006858.

Froot, K. A., & Dabora, E. M. (1999). How are stock prices affected by the location of trade? *Journal of Financial Economics*.

Fuest, C., Hugger, F., & Neumeier, F. (2022, February). Corporate profit shifting and the role of tax havens: Evidence from German country-by-country reporting data. *Journal of Economic Behavior & Organization*, *194*, 454–477. https://doi.org/10.1016/j.jebo.2021.11.016

Gala, V. D., Pagliardi, G., & Zenios, S. A. (2023, June). Global political risk and international stock returns. *Journal of Empirical Finance*, *72*, 78–102. https://doi.org/10.1016/j.jempfin.2023.03.004

Gelos, R. G., & Wei, S. (2005, December). Transparency and International Portfolio Holdings. *The Journal of Finance*, *60*(6), 2987–3020. https://doi.org/10.1111/j.1540-6261.2005.00823.x

Goetzmann, W. N., Li, L., & Rouwenhorst, K. G. (2005, January). Long-Term Global Market Correlations. *The Journal of Business*, *78*(1), 1–38. https://doi.org/10.1086/426518

Griffin, J. M. (2002). Are the fama and french factors global or country specific? *The Review of Financial Studies*, *15*(3), 783–803. http://www.jstor.org/stable/2696721.

Heston, S. L., & Rouwenhorst, K. (1994, August). Does industrial structure explain the benefits of international diversification? *Journal of Financial Economics*, *36*(1), 3–27. https://doi.org/10.1016/0304-405X(94)90028-0

Ivković, Z., & Weisbenner, S. (2005, February). Local Does as Local Is: Information Content of the Geography of Individual Investors' Common Stock Investments. *The Journal of Finance*, *60*(1), 267–306. https://doi.org/10.1111/j.1540-6261.2005.00730.x

Jegadeesh, N., & Titman, S. (1993, March). Returns to Buying Winners and Selling Losers: Implications for Stock Market Efficiency. *The Journal of Finance*, *48*(1), 65–91. https://doi.org/10.1111/j.1540-6261.1993.tb04702.x

Jory, S. R., Mishra, T., & Ngo, T. N. (2019, March). Location-specific stock market indices: an exploration. *The European Journal of Finance*, *25*(4), 305–337. https://doi.org/10.1080/1351847X.2018.1515095

Joshi, P., Outslay, E., Persson, A., Shevlin, T., & Venkat, A. (2020, December). Does Public Country-by-Country Reporting Deter Tax Avoidance and Income Shifting? Evidence

from the European Banking Industry*. *Contemporary Accounting Research*, *37*(4), 2357–2397. https://doi.org/10.1111/1911-3846.12601

Lam, S., Zhang, H., & Zhang, W. (2020, March). Does Policy Instability Matter for International Equity Markets? *International Review of Finance*, *20*(1), 155–196. https://doi.org/10.1111/irfi.12222

Levy, H., & Sarnat, M. (1970). International diversification of investment portfolios. *The American Economic Review*, *60*(4), 668–675. http://www.jstor.org/stable/1818410.

Lintner, J. (1965). The valuation of risk assets and the selection of risky investments in stock portfolios and capital budgets. *The Review of Economics and Statistics*, *47*(1), 13–37. https://doi.org/10.2307/1924119.

Markowitz, H. (1952). Portfolio selection. *The Journal of Finance*, *7*(1), 77–91. http://www.jstor.org/stable/2975974.

Mavruk, T. (2011). Local bias dynamics and the risk adjusted portfolio return. *International Journal of Banking, Accounting and Finance*, *3*(1), 91-113. https://EconPapers.repec.org/RePEc:ids:injbaf:v:3:y:2011:i:1:p:91-113.

Melas, D., Giese, G., Kouzmenko, R., Bhat, A., Kumar, N., Nagy, Z., & Taranenko, P. (2019, October). *Selected geographical issues in the global listed equity market: Analysis for the norwegian ministry of finance.* (Commissioned by the Norwegian Ministry of Finance) Retrieved from https://www.msci.com

Miralles-Quiros, M. D. M., & Miralles-Quiros, J. L. (2017, July). The role of time-varying return forecasts for improving international diversification benefits. *International Journal of Finance & Economics*, *22*(3), 201–215. https://doi.org/10.1002/ijfe.1578

Mossin, J. (1966). Equilibrium in a capital asset market. *Econometrica*, *34*(4), 768–783.

MSCI Inc. (2022, March). *Q&a: Reclassification of msci russia indexes to standalone markets status.* Retrieved from https://www.msci.com.

MSCI Inc. (2025a, April). *MSCI AC Americas Index (USD) - Index Factsheet.* Retrieved from https://www.msci.com/index-methodology.

MSCI Inc. (2025b, March). *Msci ac asia pacific index (usd) - index factsheet.* (Retrieved from msci.com) Retrieved from https://www.msci.com/index-methodology

MSCI Inc. (2025c, March). *Msci acwi index (usd) - index factsheet.* (Retrieved from

msci.com) Retrieved from https://www.msci.com/index-methodology

MSCI Inc. (2025d, March). *Msci europe and middle east index (usd) - index fact-sheet*. (Retrieved from msci.com) Retrieved from https://www.msci.com/index-methodology

Pagano, M., Röell, A. A., & Zechner, J. (2002, December). The Geography of Equity Listing: Why Do Companies List Abroad? *The Journal of Finance*, *57*(6), 2651–2694. https://doi.org/10.1111/1540-6261.00509

Petzev, I., Schrimpf, A., & Wagner, A. F. (2016). *Has the pricing of stocks become more global?* (Swiss Finance Institute Research Paper No. 15-48). Swiss Finance Institute. (Available at SSRN: https://ssrn.com/abstract=2693024 or http://dx.doi.org/10.2139/ssrn.2693024)

Pirinsky, C., & Wang, Q. (2006, August). Does Corporate Headquarters Location Matter for Stock Returns? *The Journal of Finance*, *61*(4), 1991–2015. https://doi.org/10.1111/j.1540-6261.2006.00895.x

Portes, R., & Rey, H. (2005, March). The determinants of cross-border equity flows. *Journal of International Economics*, *65*(2), 269–296. https://doi.org/10.1016/j.jinteco.2004.05.002

Pukthuanthong, K., & Roll, R. (2009, November). Global market integration: An alternative measure and its application. *Journal of Financial Economics*, *94*(2), 214–232. https://doi.org/10.1016/j.jfineco.2008.12.004

Qian, G., & Li, J. (1998, October). Multinationality, global market diversification, and risk performance for the largest U.S. firms. *Journal of International Management*, *4*(2), 149–170. https://doi.org/10.1016/S1075-4253(98)00007-6

Ross, S. A. (1976). The arbitrage theory of capital asset pricing. *Journal of Economic Theory*, *13*(3), 341–360. https://doi.org/https://doi.org/10.1016/0022-0531(76)90046-6

Rouwenhorst, K. G. (1998, February). International Momentum Strategies. *The Journal of Finance*, *53*(1), 267–284. https://doi.org/10.1111/0022-1082.95722

Sharpe, W. F. (1964, September). CAPITAL ASSET PRICES: A THEORY OF MARKET EQUILIBRIUM UNDER CONDITIONS OF RISK*. *The Journal of Finance*, *19*(3), 425–442. https://doi.org/10.1111/j.1540-6261.1964.tb02865.x

Solnik, B. H. (1977, May). TESTING INTERNATIONAL ASSET PRICING: SOME PESSIMISTIC VIEWS. *The Journal of Finance*, *32*(2), 503–512. https://doi.org/10.1111/j.1540-6261.1977.tb03288.x

Treynor, J. L. (1962). *Toward a theory of market value of risky assets*. http://dx.doi.org/10.2139/ssrn.628187.

Vermorken, M. A. M. (2011). GICS or ICB, how different is similar? *Journal of Asset Management*, *12*(1), 30–44. https://doi.org/10.1057/jam.2010.4

White, H. (1980). A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. *Econometrica*, *48*(4), 817–838. http://www.jstor.org/stable/1912934.

Yadav, M. P., Abedin, M. Z., Sinha, N., & Arya, V. (2024, January). Uncovering dynamic connectedness of Artificial intelligence stocks with agri-commodity market in wake of COVID-19 and Russia-Ukraine Invasion. *Research in International Business and Finance*, *67*, 102146. https://doi.org/10.1016/j.ribaf.2023.102146

Appendixes

Appendix 1. Top-weighted industries and supersectors

Table 16. Top-weighted ICB industries and supersectors in the Euro Stoxx 50.

Top 5 industries	Industry (%)	Top 5 Supersectors	Supersector (%)
Consumer & Discretionary	21.72%	Technology	17.05%
Financials	19.10%	Industrial & Goods & Services	14.44%
Industrials	17.42%	Consumer Products & Services	12.99%
Technology	17.05%	Banks	11.46%
Health Care	5.50%	Insurance	6.63%
Total weight (%)	80.78%		62.57%
Data as of March 28, 2024			

Appendix 2. Top-weighted sectors and sub-sectors

Table 17. Top-weighted ICB sectors and subsectors in the Euro Stoxx 50.

Top 5 Sectors	Sectors (%)	Top 5 Sub-sectors	Sub-sectors (%)
Personal Goods	12.99%	Banks	11.46%
Banks	11.46%	Technology Hardware & Equipment	9.19%
Technology Hardware & Equipment	10.34%	Clothing & Accessories	9.07%
Software & Computer Services	6.70%	Automobiles	6.26%
Non-life Insurance	6.63%	Software	5.48%
Total weight (%)	48.13%		41.46%
Data as of March 28, 2024			

Appendix 3. Rolling 3-months tracking error for monthly returns

Figure 12. Rolling 3-months tracking error for monthly returns.

Appendix 4. Rolling 12-weeks tracking error for weekly returns

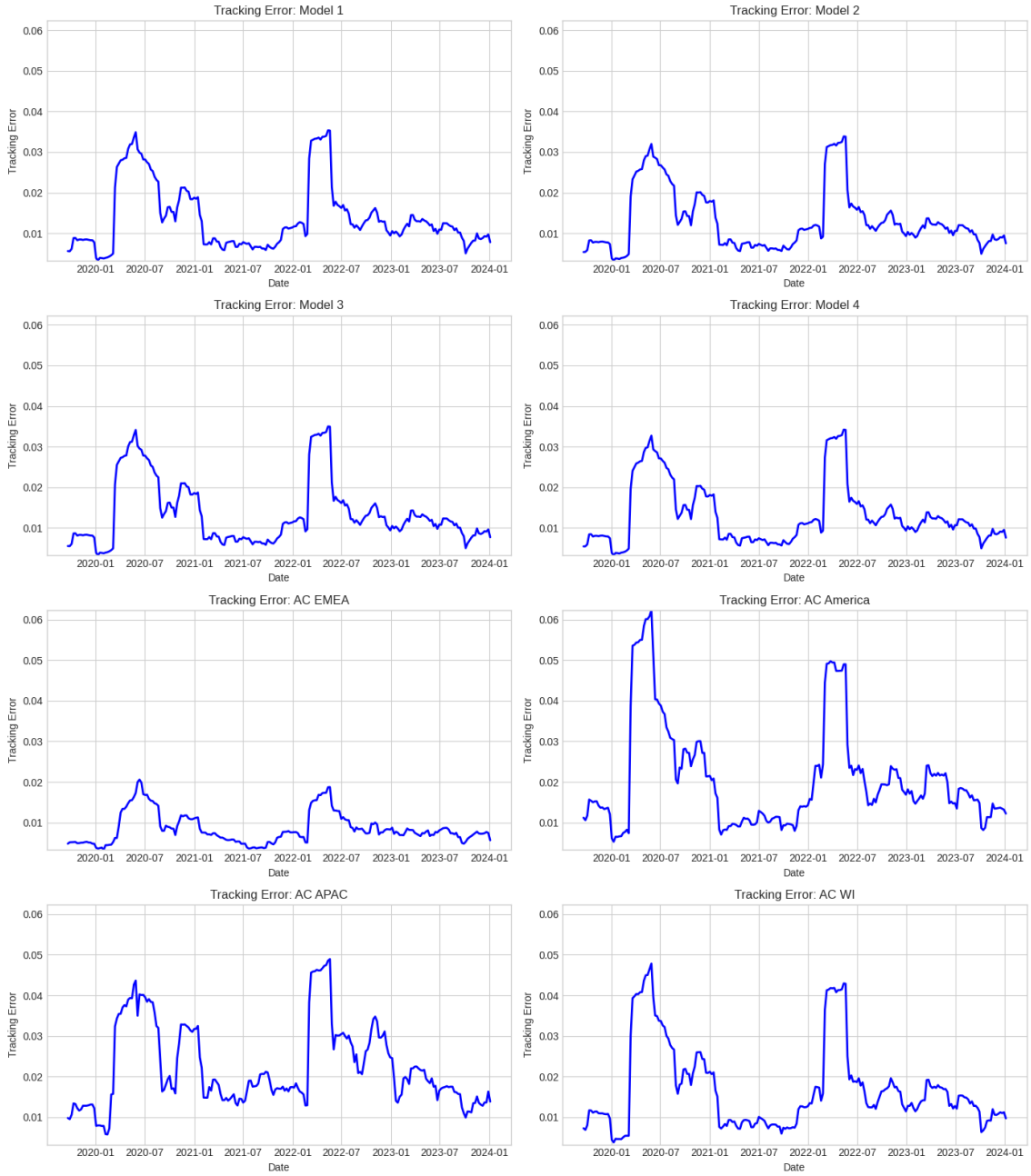

Figure 13. Rolling 12-weeks tracking error for weekly returns.

Appendix 5. Rolling 90-days tracking error for daily returns

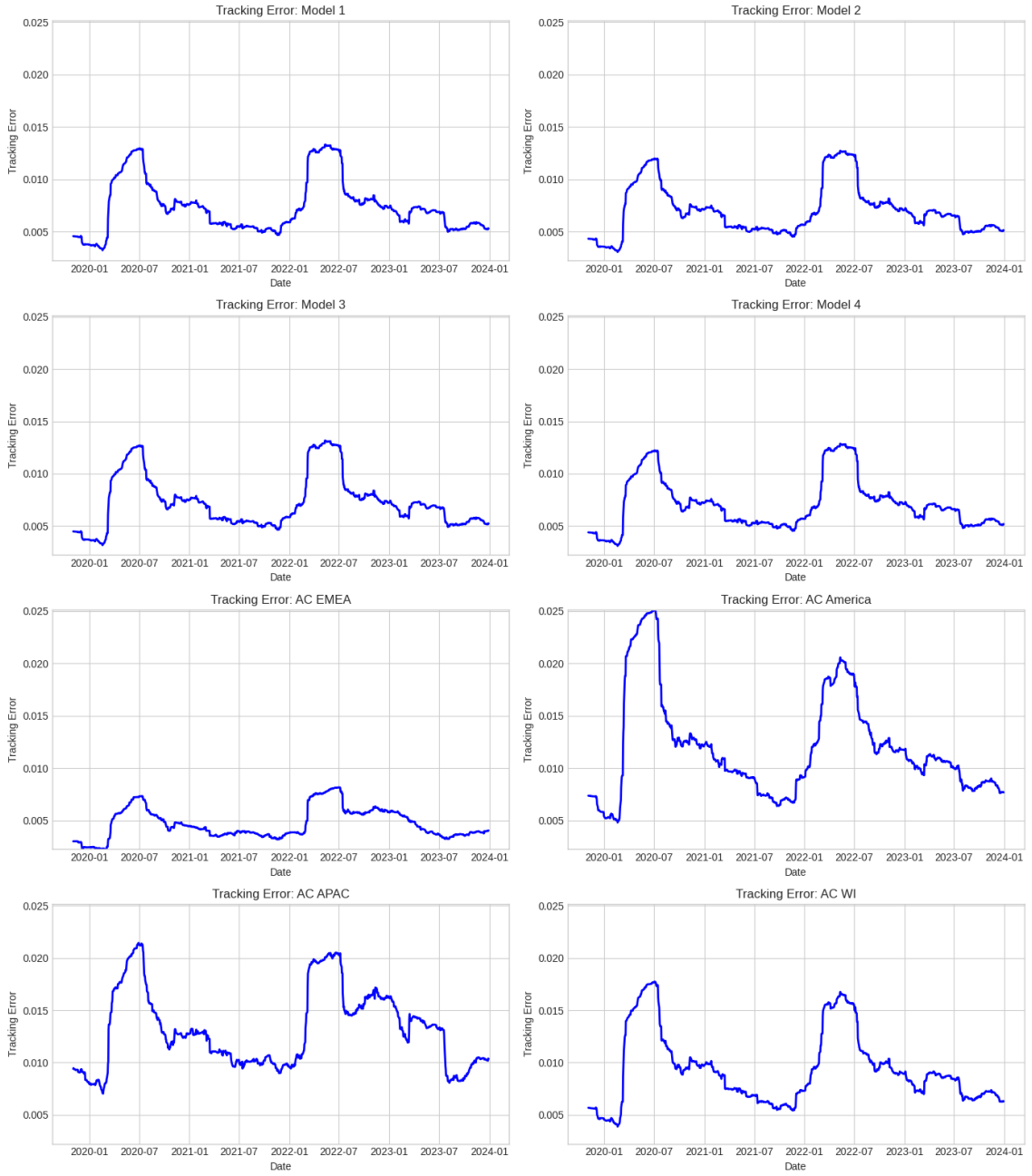

Figure 14. Rolling 90-days tracking error for daily returns.

Appendix 6. Detailed descriptive statistics for Euro Stoxx 50 constituents

Company Name	Component Count	Total Weight (%)	Weight Contribution (%)	Mean Weight	Min Weight	Max Weight	SD
ASML HLDG	20	146.91671	7.35	7.35	3.77	10.06	1.68
LVMH MOET HENNESSY	20	111.37445	5.57	5.57	3.79	7.13	0.91
SAP	20	90.9589	4.55	4.55	3.48	6.14	0.81
SANOFI	20	72.76936	3.64	3.64	2.92	4.62	0.47
SIEMENS	20	68.44291	3.42	3.42	2.82	3.96	0.29
LINDE	14	64.58798	3.23	4.61	3.82	5.55	0.53
ALLIANZ	20	59.86296	2.99	2.99	2.62	3.54	0.25
L'OREAL	20	59.67362	2.98	2.98	2.38	3.41	0.25
TOTALENERGIES	13	57.29252	2.86	4.41	3.37	5.42	0.65
SCHNEIDER ELECTRIC	20	54.10415	2.71	2.71	1.72	3.77	0.48
AIR LIQUIDE	20	50.63458	2.53	2.53	2.17	2.87	0.23
AIRBUS	20	44.30741	2.22	2.22	1.52	2.82	0.36
IBERDROLA	20	43.69714	2.18	2.18	1.67	2.64	0.26
DEUTSCHE TELEKOM	20	42.31446	2.12	2.12	1.74	2.54	0.25
BNP PARIBAS	20	40.19725	2.01	2.01	1.51	2.38	0.20
VINCI	20	38.13547	1.91	1.91	1.70	2.12	0.14
ENEL	20	36.61982	1.83	1.83	1.31	2.58	0.43
BCO SANTANDER	20	36.34001	1.82	1.82	1.12	2.36	0.26
BAYER	20	36.14067	1.81	1.81	0.76	2.80	0.56
BASF	20	34.80145	1.74	1.74	1.18	2.30	0.39
ANHEUSER-BUSCH INBEV	20	34.41368	1.72	1.72	1.38	2.88	0.34
AXA	20	34.1847	1.71	1.71	1.38	1.92	0.14
SAFRAN	20	32.74275	1.64	1.64	1.26	2.23	0.30
ESSILORLUXOTTICA	20	32.56116	1.63	1.63	1.44	1.81	0.13
ADIDAS	20	28.75051	1.44	1.44	0.74	2.18	0.51
TOTAL	7	28.6444	1.43	4.09	3.28	4.99	0.58
DEUTSCHE POST	20	27.92963	1.40	1.40	1.06	1.90	0.23
MUENCHENER RUECK	20	27.74105	1.39	1.39	1.09	1.83	0.21
Kering	20	27.49376	1.37	1.37	0.71	1.82	0.33
ING GRP	20	27.37764	1.37	1.37	0.98	1.62	0.19
DANONE	20	26.85053	1.34	1.34	1.07	2.04	0.29
INTESA SANPAOLO	20	26.82697	1.34	1.34	1.20	1.64	0.12
Prosus	16	25.70498	1.29	1.61	1.22	2.16	0.29
ADYEN	16	24.75499	1.24	1.55	0.68	2.24	0.44
Industria de Diseno Textil SA	20	23.15614	1.16	1.16	0.75	1.51	0.19
DEUTSCHE BOERSE	20	21.3757	1.07	1.07	0.86	1.32	0.12
HERMES INTERNATIONAL	11	21.23147	1.06	1.93	1.46	2.33	0.30
ENI	20	20.54212	1.03	1.03	0.71	1.40	0.17
BCO BILBAO VIZCAYA ARGENTARIA	16	20.3459	1.02	1.27	0.88	1.80	0.24
INFINEON TECHNOLOGIES	14	19.88953	0.99	1.42	1.15	1.64	0.18
VOLKSWAGEN PREF	20	19.71352	0.99	0.99	0.64	1.52	0.22
PERNOD RICARD	16	19.36487	0.97	1.21	0.74	1.52	0.21
AHOLD DELHAIZE	20	19.29425	0.96	0.96	0.74	1.20	0.13
BMW	20	18.01745	0.90	0.90	0.74	1.15	0.10
DAIMLER	10	17.24559	0.86	1.72	1.15	2.22	0.36
MERCEDES-BENZ GROUP	10	17.03192	0.85	1.70	1.51	1.87	0.12
CRH	16	16.92283	0.85	1.06	0.94	1.21	0.07
PHILIPS	12	15.82141	0.79	1.32	0.70	1.66	0.33
STELLANTIS	12	14.89794	0.74	1.24	1.03	1.69	0.19
UNILEVER NV	5	14.76684	0.74	2.95	2.79	3.15	0.15
FLUTTER ENTERTAINMENT	12	10.46578	0.52	0.87	0.63	1.06	0.15
NOKIA	14	10.28992	0.51	0.73	0.49	1.02	0.17
Vonovia SE	12	10.22875	0.51	0.85	0.39	1.27	0.30
NORDEA BANK	8	9.57363	0.48	1.20	1.03	1.32	0.10
UNICREDIT	6	8.54229	0.43	1.42	1.09	1.70	0.24
AMADEUS IT GROUP	8	7.94764	0.40	0.99	0.90	1.17	0.11
KONE B	8	7.21222	0.36	0.90	0.65	1.29	0.21
ENGIE	8	7.16486	0.36	0.90	0.72	1.07	0.11
VIVENDI	8	6.7064	0.34	0.84	0.72	0.88	0.05
FERRARI	4	4.84383	0.24	1.21	1.11	1.32	0.12
TELEFONICA	4	4.21586	0.21	1.05	0.86	1.28	0.18
ORANGE	4	4.19223	0.21	1.05	0.91	1.16	0.11
SAINT GOBAIN	4	4.13054	0.21	1.03	0.98	1.08	0.04
WOLTERS KLUWER	3	3.13268	0.16	1.04	1.00	1.13	0.07
GRP SOCIETE GENERALE	4	3.02795	0.15	0.76	0.55	0.98	0.19
FRESENIUS	4	2.96	0.15	0.74	0.70	0.79	0.04
UMG	1	0.59948	0.03	0.60	0.60	0.60	0.00
Average	**14.93**	**29.85**	**1.49**	**1.85**	**1.39**	**2.34**	**0.28**
Median	**20**	**24.75**	**1.24**	**1.42**	**1.09**	**1.83**	**0.22**
Max	**20**	**146.92**	**7.35**	**7.35**	**3.82**	**10.06**	**1.68**
Min	**1**	**0.60**	**0.03**	**0.60**	**0.39**	**0.60**	**0.08**

Table 18. Descriptive statistics for each constituent from September 30, 2019 to June 28, 2024.

Appendix 7. Historical constituents and their industries

Company	ISIN	Industry Name (ICB)	Supersector name (ICB)
TOTAL	FR0000120271	Energy	Energy
SAP	DE0007164600	Technology	Technology
LINDE	IE00BZ12WP82	Basic Materials	Chemicals
SANOFI	FR0000120578	Health Care	Health Care
LVMH MOET HENNESSY	FR0000121014	Consumer Discretionary	Consumer Products and Services
ASML HLDG	NL0010273215	Technology	Technology
ALLIANZ	DE0008404005	Financials	Insurance
UNILEVER NV	NL0000388619	Consumer Staples	Personal Care, Drug and Grocery Stores
SIEMENS	DE0007236101	Industrials	Industrial Goods and Services
ANHEUSER-BUSCH INBEV	BE0974293251	Consumer Staples	Food, Beverage and Tobacco
AIRBUS	NL0000235190	Industrials	Industrial Goods and Services
L'OREAL	FR0000120321	Consumer Discretionary	Consumer Products and Services
BAYER	DE000BAY0017	Health Care	Health Care
BCO SANTANDER	ES0113900J37	Financials	Banks
BASF	DE000BASF111	Basic Materials	Chemicals
AIR LIQUIDE	FR0000120073	Basic Materials	Chemicals
IBERDROLA	ES0144580Y14	Utilities	Utilities
VINCI	FR0000125486	Industrials	Construction and Materials
ENEL	IT0003128367	Utilities	Utilities
ADIDAS	DE000A1EWWW0	Consumer Discretionary	Consumer Products and Services
SAFRAN	FR0000073272	Industrials	Industrial Goods and Services
DANONE	FR0000120644	Consumer Staples	Food, Beverage and Tobacco
BNP PARIBAS	FR0000131104	Financials	Banks
DEUTSCHE TELEKOM	DE0005557508	Telecommunications	Telecommunication
AXA	FR0000120628	Financials	Insurance
SCHNEIDER ELECTRIC	FR0000121972	Industrials	Industrial Goods and Services
ESSILORLUXOTTICA	FR0000121667	Health Care	Health Care
DAIMLER	DE0007100000	Consumer Discretionary	Automobiles and Parts
PHILIPS	NL0000009538	Health Care	Health Care
ING GRP	NL0011821202	Financials	Banks
ENI	IT0003132476	Energy	Energy
INTESA SANPAOLO	IT0000072618	Financials	Banks
Kering	FR0000121485	Consumer Discretionary	Consumer Products and Services
MUENCHENER RUECK	DE0008430026	Financials	Insurance
TELEFONICA	ES0178430E18	Telecommunications	Telecommunication
BCO BILBAO VIZCAYA ARGENTARIA	ES0113211835	Financials	Banks
Industria de Diseno Textil SA	ES0148396007	Consumer Discretionary	Retail
DEUTSCHE POST	DE0005552004	Industrials	Industrial Goods and Services
ORANGE	FR0000133308	Telecommunications	Telecommunication
AMADEUS IT GROUP	ES0109067019	Technology	Technology
VOLKSWAGEN PREF	DE0007664039	Consumer Discretionary	Automobiles and Parts
DEUTSCHE BOERSE	DE0005810055	Financials	Financial Services
ENGIE	FR0010208488	Utilities	Utilities
NOKIA	FI0009000681	Telecommunications	Telecommunication
AHOLD DELHAIZE	NL0011794037	Consumer Staples	Personal Care, Drug and Grocery Stores
CRH	IE0001827041	Industrials	Construction and Materials
VIVENDI	FR0000127771	Consumer Discretionary	Media
GRP SOCIETE GENERALE	FR0000130809	Financials	Banks
BMW	DE0005190003	Consumer Discretionary	Automobiles and Parts
FRESENIUS	DE0005785604	Health Care	Health Care
ADYEN	NL0012969182	Industrials	Industrial Goods and Services
Prosus	NL0013654783	Technology	Technology
KONE B	FI0009013403	Industrials	Industrial Goods and Services
Vonovia SE	DE000A1ML7J1	Financials	Real Estate
PERNOD RICARD	FR0000120693	Consumer Staples	Food, Beverage and Tobacco
FLUTTER ENTERTAINMENT	IE00BWT6H894	Consumer Discretionary	Travel and Leisure
INFINEON TECHNOLOGIES	DE0006231004	Technology	Technology
TOTALENERGIES	FR0000120271	Energy	Energy
STELLANTIS	NL00150001Q9	Consumer Discretionary	Automobiles and Parts
UMG	NL0015000IY2	Consumer Discretionary	Media
HERMES INTERNATIONAL	FR0000052292	Consumer Discretionary	Consumer Products and Services
MERCEDES-BENZ GROUP	DE0007100000	Consumer Discretionary	Automobiles and Parts
NORDEA BANK	FI4000297767	Financials	Banks
UNICREDIT	IT0005239360	Financials	Banks
FERRARI	NL0011585146	Consumer Discretionary	Automobiles and Parts
SAINT GOBAIN	FR0000125007	Industrials	Construction and Materials
WOLTERS KLUWER	NL0000395903	Consumer Discretionary	Media

Table 19. Historical constituents and their industries from September 30, 2019 to June 28, 2024.