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Thesis Abstract

Functional Depth for Analyzing Data on European Insurance Market Characteristics

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1. Introduction

The introduction of this study sets the stage for a comprehensive exploration of the challenges and dynamics surrounding the **Single European Insurance Market (SEIM)**. It highlights the importance of understanding the mechanisms that drive insurance integration within the European Union (EU), particularly in light of recent economic disruptions such as the financial crisis of 2008 and the COVID-19 pandemic. These events have significantly impacted the development of national insurance markets, leading to varying degrees of convergence and homogeneity across Europe. This study proposes a methodological framework utilizing an advanced Functional Clustering (FC) (Dai et al., 2021) method to analyze the Composite Insurance Market Index (CIMI) of 35 European countries from 2004 to 2021. The FC method is nonparametric and robust against skewed distributions, allowing for a detailed analysis of insurance market development via the functional ordering of CIMI curves. A dynamic entropy-based approach that determines the weight coefficient of each insurance market indicator (IMI) is considered in the aggregation process to establish the CIMI.

This study aims to address two critical research questions: whether national insurance markets are converging over time and whether the observed heterogeneity in market development has resulted in distinct country groupings pursuing different integration speeds. The study emphasizes the necessity of this analysis in informing policymakers and enhancing the understanding of the EU's insurance landscape, ultimately contributing to the goal of achieving a more integrated and homogeneous insurance market across Europe.

The study highlights the need for policymakers to consider factors affecting insurance development and to propose measures that could enhance homogeneity in the European insurance market. It also suggests further analysis on the associations of insurance market development across Europe with various factors exposed to at different cluster areas produced by the FC method.

The study contributes to the literature on SEIM by providing insights into the dynamics of insurance market integration in Europe, emphasizing the importance of understanding convergence, homogeneity and the economic, institutional, and sociodemographic factors affecting insurance demand in achieving a unified market.

2. Objectives, Research Questions and Contributions

The central objective of the present study is to propose a new methodology for exploring whether the European insurance market is becoming more homogeneous or more diverse and whether it is displaying convergence or divergence from the European target of SEIM. The main rationale behind pursuing this objective is to show the current level of realization of SEIM and how far European integration has brought national insurance markets, when analyzing insurance data with FDA approach. To achieve this objective, a variety of insurance market indicators that describe each national insurance market characteristics are carefully chosen to calculate the CIMI after the functional adjustment of Shannon entropy weights attributed to each one of these indicators. Subsequently, FDA is implemented to conduct an empirical examination of the CIMI dynamics across three distinct sets of European countries, namely old-EU, new-EU, and non-EU. These sets of countries encompass national insurance markets with diverse attributes, thereby facilitating a comprehensive understanding of the insurance market development patterns in Europe throughout the entire duration of the study. The FDA is performed following a novel functional clustering tool, the FC method, that is developed and utilized to process and cluster the insurance data efficiently, leading to the extraction of valuable graphical information and insights with respect to two overarching research questions:

- Research Question I: Is the European insurance market homogenous?
- Research Question II: Is the European insurance market converging?

However, in the case that the SEIM is not yet realized, there is an additional methodology step that focuses on identifying possible reasons for the lack of a common insurance market development pattern in Europe. Then, this step requires to present the major challenges and obstacles remaining before SEIM can function as planned. The objective at this point is to recommend several interventions that could potentially contribute to the process of achieving a more uniform European insurance market. It is also the point where this study will allow for a mixed effect model fit to the data, which responds to the third research question:

- Research Question III: What factors affect the European insurance development?

by revealing the most significant economic, institutional, and sociodemographic factors of insurance market development within each identified cluster. The findings regarding this last RQ provides valuable information to policymakers and industry stakeholders to make informed decisions that facilitate the process of achieving SEIM.

For the newly proposed methodology, we have three contributions. First, this study intends to develop a dynamic entropy-based approach to determine the weight coefficient of each IMI in the aggregation process to establish the CIMI for individual countries. The selection of this methodology is based on the need to accurately represent the evolving significance of IMI over time. While this approach is commonly applied in studies related to energy security evaluations (Bamisile et al., 2021) or decision-making processes (Lotfi & Fallahnejad, 2010) its utilization within the context of insurance remains unexplored. This study not only addresses this existing gap but also takes a step further by incorporating the recently developed functional extension of the entropy weight method as outlined in Wang, D. et al. (2022). Subsequently, the traditional Shannon information entropy weight is expanded to encompass the domain of functional curves, adding a new dimension to the objective weighting methods and enabling a more nuanced understanding of the relative importance of IMI.

Second, we utilize FDA approach to the European insurance market data to cluster countries in terms of their insurance market development patterns. This study uses a recently developed FC method to extract and analyze the underlying information present in insurance market data, aiming to provide the recent and most updated evidence on the comparison of the insurance markets in Europe and on their complex dynamics in-depth. This FC method, which contrary to the standard clustering methods, offers the advantage of capturing the variability mechanisms of data by considering the whole curve values from the historical data. Additionally, this FC method, in contrast to other functional clustering methods, provides a unique benefit of considering the magnitude and the shape sources of the curves. Surprisingly, there has been a noticeable absence of functional clustering analysis applications within the realms of insurance economics. To our best knowledge, this particular study stands out as the pioneering investigation into the dynamics of insurance market development variations for European countries, focusing specifically on the graphical interpretation of the obtained clustering results. By unraveling in such way the dynamic

mechanisms of insurance market data, the FC method uncovers insights regarding the functioning and the development potential or gap of national insurance markets. These insight dimensions have still remained largely unexplored and are incredibly beneficial if they are appropriately analyzed to the decision-making process of policy makers towards the goal of SEIM.

Third, this study examines associations of insurance market development across Europe with various factors exposed to at different cluster areas produced by the FC method. As most of the studies (using time-series or cross-section econometric models) neglect the dynamic changes across time and across clusters in the relationship of the insurance market development and its factors, the mixed effect model is proposed to address such issues in this context. In this model random effects are introduced to incorporate the between-individual variation and within-individual correlation in the data. The structure of the model involves besides the fixed and random effects parameters the facility of an auto-correlation structure, which deals with the fact that the multiple measurements of an IMI on the same countries are correlated, the heteroscedasticity of residuals and the presence of missing data. The mixed effects models are relatively new in the statistical modeling field and surprisingly not employed in the analysis of longitudinal data situations such as those arise in the studies on the determinants of insurance development. From this point of view, this study presents an unfamiliar fitting model that offers a valid approach to the quest for insurance determinants across European countries. The exploration of factors likely to influence insurance market development aims to present its essential elements upon which policy makers should focus before they undertake any intervention actions to support insurance markets

3. Methodology

Our proposed methodological framework for exploring the characteristics of insurance industry in Europe consists of the following steps:

- Choose the IMIs that characterize insurance market development of country under three qualitative consideration (**Table 1**).

Table 1: Pillars and description of Insurance market Indicators

Pillar	Abbreviation	Description [Code]
1	LtT	Life to Total (Premiums) [X1]
	LIP	Life Insurance Penetration [X2]
	LID	Life Insurance Density [X3]
	NLIP	Non-life Insurance Penetration [X4]
	NLID	Non-life Insurance Density [X5]
	RGNL	Real Growth Non-life (Premiums) [X6]
	RGL	Real Growth Life (Premiums) [X7]
2	TIP	Total Insurance Penetration [X8]
	TID	Total Insurance Density [X9]
	RGT	Real Growth Total (Premiums) [X10]
	NLtT	Non-life to Total (Premiums) [X11]

Source: Own processing

Remark 1: In line with Pividori et al. (2019), we introduce, besides the Pearson, Spearman and Kendall's Rank correlation coefficients, an easy-to-use correlation coefficient using machine learning models. In particular, this is a functional clustering-based correlation coefficient (FCBCC), which captures linear and nonlinear patterns in data by comparing clustering solutions produced by the FC method. The FCBCC procedure allows isolating the group of IMIs that lead to similar clustering results of the set of European countries and is found in Dudek and Walesiak (2020). We follow an adjusted version of this procedure cater to our needs.

- Construct the pillars inherent in the IMIs data based on correlation coefficient methods (Pearson, Spearman, Kendall and FCBCC), such that no information present in the selected IMIs is missed.
- Aggregate the selected IMIs and the related pillars for each country to construct the CIMI using the Shannon weight approach adjusted accordingly to derive functional weights.
- Choose the appropriate data sources (e.g., CIMI raw data for magnitude curve set, first-order differences or derivatives or sequential transformations of the CIMI raw data for the shape curve set)
- Choose the functional ordering which allows for intrinsic graphical interpretation (IGI), and which gives the same weight to every chosen source (e.g., the Studentized maximum ordering, the area rank ordering etc.).
- Compute the dissimilarity matrix from the set of differences.
- Determine the optimal number of clusters.
- Apply PAM and Ward's method using the dissimilarity matrix of the previous step.
- Plot for each clustering method in the previous step the resulted clusters together with their central region with IGI.
- Explain the results and respond to the research questions.

Remark 2: This study also clarifies the association between time-related insurance market development patterns, represented by CIMI curves, and various insurance market factors, with the ultimate aim of optimizing policymaker's decision-making. Broad coverage of factors from economic to institutional and sociodemographic, data availability and previous use in various studies should be the basis for selecting potentially associated factors as long as they have not a high proportion of missing values (<50%) (Wang, X. et al., 2022).

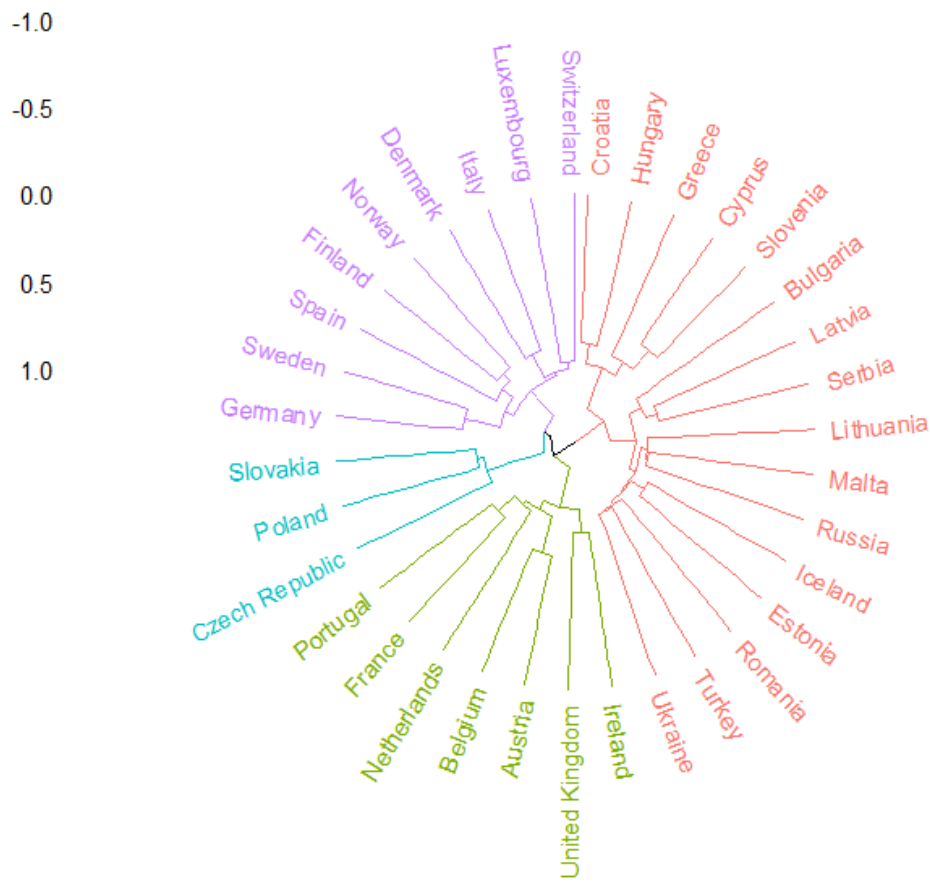
- Choose and identify factors significantly affecting insurance market development in each formed cluster of European countries using a linear mixed effect model.
- Provide recommendations for insurance policymakers regarding country-tailored insurance market interventions that may attempt to promote the SEIM.

4. Results

The analysis reveals a fragmented European insurance market, with four distinct clusters of countries, each showing varying levels of development (**Figure 1**). The 2024 updated Dow Jones Indexes Country Classification supported by various economic, institutional, and sociodemographic considerations and the obtained clustering of insurance market development patterns (**Figure 2**) provide the labels and characteristics of the identified clusters.

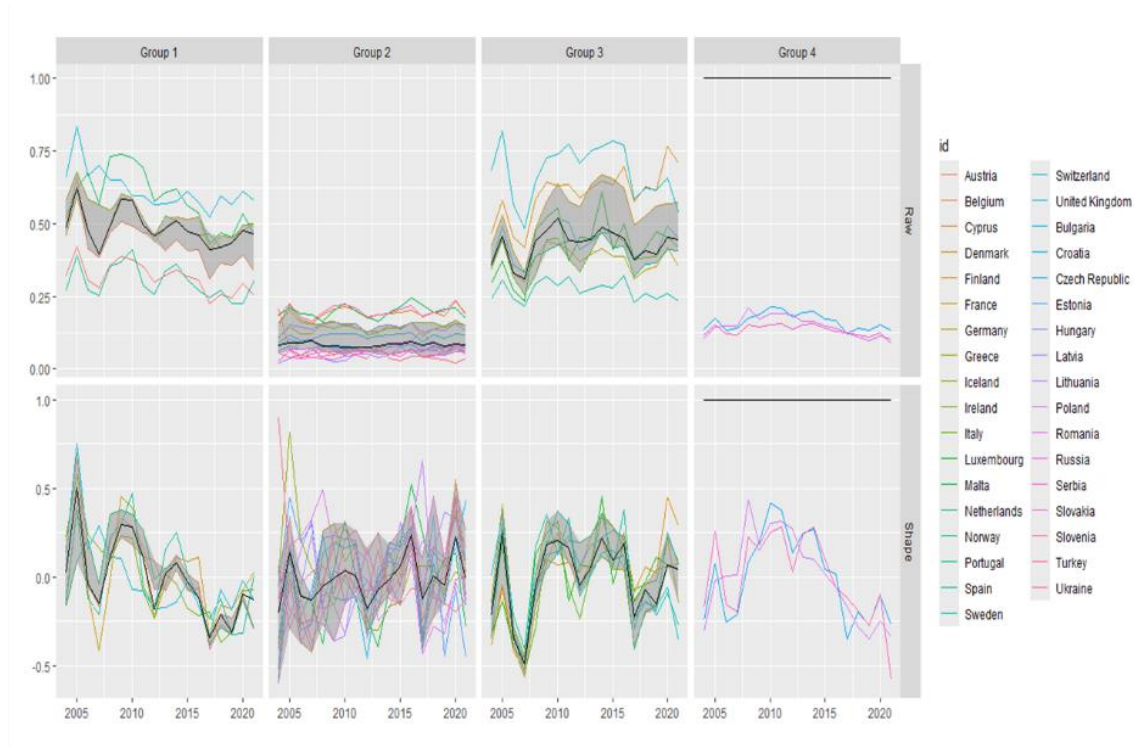
- **Cluster 1: Developed markets, high and decreasing insurance market development**
- **Cluster 2: Emerging and Frontier markets, low to medium and slightly increasing insurance market development**
- **Cluster 3: Developed markets, high and wave-like insurance market development**
- **Cluster 4: Emerging and Frontier markets, low to medium and arch-like insurance development**

Figure 1 Functional Clustering of countries (Ward's method) - Dendrogram



Source: Own processing

Figure 2 Functional Clustering of countries (Ward's method) – Magnitude and Shape curves of national insurance market development



Source: Own processing

Despite the establishment of SEIM, overall integration remains low, particularly among newer EU member states, with only a few exceptions showing upward trends in insurance development. The study finds no evidence of convergence among national insurance markets, as significant variability persists within clusters. External factors, such as the financial crisis and COVID-19 pandemic, have exacerbated existing trends, leading to declines in insurance market development levels across most countries.

The study highlights the need for cluster-tailored policy interventions to address the challenges hindering the realization of a more integrated insurance landscape in Europe. Let's break down what are the recommendations for each cluster.

- **Cluster 1** emphasizes the need for economic, institutional, and sociodemographic advancements to innovate insurance markets, highlighting the role of personalized products and financial literacy in addressing underinsurance and imperfect information in demand and supply dynamics.

- **Cluster 2** focuses on enhancing institutional quality and economic growth, advocating for governance reforms to build consumer trust, and suggesting mandatory insurance and educational along with tax relief incentives to improve insurance uptake in countries facing corruption and regulatory inconsistencies.
- **Cluster 3** calls for maintaining high institutional standards while promoting financial literacy and urbanization, stressing the importance of transparency and tailored insurance products to address consumer needs and mitigate the effects of misleading information in the insurance market.
- **Cluster 4** identifies the need for targeted governance policies and educational initiatives to enhance financial literacy, recommending comprehensive reforms, including mandatory insurance, to protect against major risks and improve market soundness through cultural shifts and incentives.

The policymakers' interventions and cluster-tailored policies described earlier are also supported by building a fixed functional relationship between insurance market development and various factors besides economic growth. To reply to the RQ of what factors affect the European insurance market development a mixed effect model that can capture the linear relationship between different predictors and insurance market development in each of the four homogeneous group of European countries. A recent application of mixed effect models on insurance area is found in the study of Athanasiadis et al. (2023).

This study used the following variables to give insight into the various economic, institutional, and sociodemographic factors affecting insurance market development that, consequently, can help policymakers develop effective strategies for creating a SEIM:

1. Insurance market development (proxy: Composite Insurance Market Index, CIMI)
2. Economic growth (proxy: GDP growth, GDP_GR)
3. Income (proxy: GDP per capita, GDP_PC).
4. Interest (Long-term interest rate, INT).
5. Inflation (proxy: GDP deflator, INF).
6. Financial Development (proxy: Financial Development Index, FDI).
7. Urbanization (urban population, URBAN).
8. Education (proxy: tertiary school enrollment, EDUC).
9. Unemployment (unemployment, total, UNEMP).

10. Institutional Development (Institutional Development Index, IDI).

11. Sustainable Development (Sustainable Development Goals Index Score, SDGIS).

12. Globalization (KOF Globalization Index, KOFIG).

The results from the linear mixed effect model led to several important points about insurance development. First, in developed markets of Cluster 1, where traditional factors like income growth no longer significantly boost insurance demand, it is imperative for policymakers to foster innovation in insurance plans, such as cyber risk insurance or climate-related coverage, which may address the dynamic insurance risks arising in highly developed markets. Moreover, a comprehensive strategy towards the development of insurance markets should be adopted, catering to the needs of low-income groups (through microinsurance) alongside the middle class. Initiatives that provide tax relief could also convince consumers to allocate their surplus income towards insurance products, thereby increasing insurance demand.

Second, the findings regarding the relationship between economic growth and insurance demand appear counterintuitive for Clusters 2 and Cluster 3, as economic expansion does not necessarily ensure an increase in insurance uptake. Hence, an emphasis on sustainable economic growth that fosters equitable income distribution and degrowth policies, tailored to each cluster's context, should be prioritized to enhance insurance demand.

Third, financial literacy, particularly within Cluster 4, has been identified as a significant catalyst for insurance adoption; thus, policymakers in these countries should prioritize educational initiatives that elevate risk awareness and influence consumer behavior regarding insurance, thereby increasing demand.

Fourth, globalization appears to exert a detrimental effect on the development of insurance markets in both developed (Cluster 1) and emerging and frontier (Cluster 4) markets, thereby highlighting the necessity for regulatory frameworks that support international collaboration while alleviating the risks associated with global market integration.

Fifth, across all clusters, with the exception of Cluster 1, interest rates are observed to have a notably negative impact on insurance markets, indicating that policymakers ought to

contemplate monetary policies aimed at stabilizing interest rates or promoting insurance products that are insulated from such fluctuations.

Finally, enhancing employment rates, particularly in emerging and frontier markets (Cluster 4), is essential for advancing insurance development. Policymakers should concentrate on strategies that facilitate job creation, as elevated employment levels appear to correlate with increased financial security and a heightened propensity to accept insurance.

The current state of the European insurance market reflects a complex interplay of heterogeneity and divergence, necessitating further investigation into the underlying reasons for the lack of a common development pattern. The study contributes to this end by enhancing the understanding of insurance market dynamics in Europe and suggesting actionable strategies to promote integration and development across diverse national markets.

5. Limitations and future research

There are a number of limitations in the current study. First, it is limited to collecting only a standard set of IMIs from the European countries; therefore, it may not be possible to generalize these results for a larger European context. This means that the number of countries in this analysis should be increased adding more non-EU countries or even, for future research's sake, can be extended to include world countries.

Considering that the IMIs in this study cover a long period and numerous European countries, except for the indicators used in this study, the indicators used in most other studies cannot be employed because many missing values exist, and not for all countries these indicators are available or easily accessible. Consequently, the number of indicators selected when setting the evaluation of CIMI regarding the insurance market development level is not as comprehensive as in other studies and should be increased. The FC method applied to insurance market development needs to be improved to handle missing data. For guaranteeing the robustness of conclusions derived from using the time dependent CIMI functions a sensitivity analysis should be conducted in future by assigning a variety of dimensional weights to each pillar. At this point, one could separate IMIs into several pillars or broader categories based on qualitative criteria and not on the correlation between them, such as premiums, investments and market concentration, provided that there are available data for each selected IMI.

The selected factors affecting insurance market development is not exclusive and exhaustive. They are based on expert judgement and serve the purpose of this statistical analysis. This suggests that future studies may find other representative indicators in the insurance context to include in their analysis. Then, the use of functional regression models in analyzing the impact of these factors provides a solid foundation for future research into other or the same selected factors affecting insurance development. Moreover, these functional models provide policymakers a tool for inferring a rough estimate of insurance market development based on GDP growth (economic growth) or other factors whose data are easily accessible.

In summary, the paper not only fills a critical gap in the literature regarding insurance market dynamics but also provides actionable insights for policymakers, emphasizing the

need for targeted interventions to enhance the development of insurance markets across Europe. All in all, the findings of this study should be viewed in light of the limitations, but it provides solid information and a contribution to future research into insurance market development analysis.

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