SPES

Sustainability
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D4.2 Public Attention Towards Sustainability in the EU: An Exploration of Google Trends Data

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1. Introduction

Sustainability is a multi-dimensional concept (Biggeri et al., 2023; Rockström et al., 2023) and its definition has evolved over time to encompass several environmental, social and economic factors (Hajian and Kashani, 2021). Europe is currently faced with a cost-of-living crisis (Müller, 2023), democratic backsliding (Gora & de Wilde, 2020), and a triple planetary crisis of climate change, pollution, and biodiversity loss (United nations, 2022). As the European Union grapples with these interlinked crises, sustainability offers a framework for balancing economic stability, social equity, and environmental resilience. The need to understand European attention towards sustainability thus becomes increasingly important to help policymakers design effective regulations, businesses to adopt greener practices, and citizens to engage in sustainable behaviours. Additionally, European attention toward sustainability influences global efforts to combat climate change, given the EU's role as a key actor in international environmental governance. By studying these attentions, political actors can assess the effectiveness of current policies, identify gaps in public engagement, and propose strategies to foster a more sustainable and equitable future.

Public attention to sustainability has generally increased in Europe over the past three decades, as indicated by numerous studies analysing trends in media coverage and public discourse. For instance, Holt and Barkemeyer (2012) observed an upward trend in sustainability-related topics in 112 newspapers from 39 countries between 1990 and 2008, suggesting a growing global awareness of environmental and social sustainability issues. Similarly, Hase et al. (2021) found considerable media attention to climate change between 2006 and 2018, although such attention plateaued towards the end of the timeframe. Furthermore, a number of studies have showed an increased public engagement with sustainability issues within particular national contexts (e.g. Revez et al., 2022) or by chronicling specific social movements such as Fridays for Future and Extinction Rebellion (e.g. Fisher and Nasrin, 2020; Moor et al., 2020).

However, given the difficulty of measuring public attention towards a topic directly, most large-scale analyses of public attention to sustainability rely on media coverage as a proxy for public interest and attention. Such practices are grounded in the large body of literature which theorizes news media's ability to influence which issues receive public attention and how they are perceived (e.g. Baumgartner & Jones, 1991; Downs, 1998; Wollin, 1999). However, as illustrated by Holt and Barkemeyer (2012), there is no consensus as of the exact relationship between public attention, policy work and media coverage and depending on the analytical model of choice, the conclusions drawn regarding public attention based on news media coverage of an issue can vary drastically.

Thus, we suggest an alternative method for conducting large-scale analysis of public attention using Google Trends. Google Trends is a service operated by Google, which offers insights into what topics attract particular interest at a given time and location, based on the relative volume of searches associated with those topics on the provider's search engine. Despite issues of statistical representativity and methodological opacity typical of "big data" research (Boyd and Crawford, 2012; Melon, 2013), the large-scale, real-time and fine-grained nature of Google's data about the daily search activities within the EU configures Google Trends data as a valuable and more direct source of information on the dynamics and composition of public attention towards certain issues.

Whereas Google Trends has found prevalent application in studying health-related phenomena and specifically the spreading of illness (Brunori et al., 2022; Carniero and Mylonakis, 2009; Ginsberg et al., 2009), distant-reading of a large corpus of academic articles (Ballerini et al., 2024) suggests that Google Trends data have already found application in the study of phenomena related to

sustainability (Boss et al., 2023; Dancy and Farris, 2024; Portugal-Nunes et al, 2023). As the concept of sustainability is constantly evolving, this research approaches the notion of sustainability through the principle of "reverse black-boxing" derived from actor-network theory (Latour 2005): considering the variability of definitions associated to the term, instead of applying existing assumptions on what sustainability means in a certain point in time and in space. Following the Google Trends data, we thus aim to unfold the ways in which the term sustainability emerges from the interaction between regional user search practices and Google's knowledge definitions.

In this paper we present some of the analytical directions that emerged from the exploration of specific data collected through Google's private Trends API between 2013-2023. Our research questions are:

- RQ1: How does the public attention towards sustainability evolve over time and across EU countries?
- RQ2: What topics associated with sustainability are the most prominent within EU publics?

Our analysis of the relative volume of Google searches reveals a steady increase in the public interest towards sustainability since 2018, with notable regional disparities. Western European countries, particularly the Netherlands and Denmark, consistently show higher levels of engagement compared to their Eastern counterparts. Additionally, the analysis of the topics associated with sustainability highlights the dominance of themes like Energy, Sustainable Development, and Environment, though topics related to economic and corporate issues also play a prominent role, suggesting that sustainability is often viewed through an organizational lens. Emerging topics like Fashion and declining ones like Agriculture further reflect the dynamic nature of the dimensions that users associate with sustainability. The distribution of these topics across countries shows a general spread of common themes, but also reveals unique country-specific patterns, indicating varying levels of integration and diverse associations with sustainability across the EU.

The remainder of the article is structured as follows. The Methods section details the data collection strategy, discusses key operational choices, describes the datasets, and outlines the analysis approach. In the Findings section we present and comment upon our three main analytical directions–Trend Analysis, Topic Analysis, and Network Clustering. In the Conclusion section we critically engage with the findings and the process in order to draw attention to further analytical potential as well as important limitations associated with working with Google Trends data to study the dynamics and composition of public attention.

2. Methods

This section provides an overview of the methodological strategies adopted. First, we briefly review different approaches to obtain Google Trends data, and document how we were granted access to Google's Trends API. Then we introduce the two classes of data that we worked with: *InterestOverTime* and *Top/RisingTrends*. Finally, we detail our analytical strategy.

2.1 Google Trends' Interface vs. Google's Trends API

Google Trends data can be accessed both through a website interface and through a programming interface. The Google Trends' website interface provides an interactive dashboard with various analytical functions, as well as the possibility to export data in .csv format for further analysis. Filtering options include location and timeframe, and comparisons among different search terms within the same query are possible. However, as each query and data export needs to be performed manually, the limitations for large-scale analysis become obvious.

In order to collect structured data based on spatio-temporal patterns at scale, a possibility is that of screen scraping – i.e., automatically extracting data from the display output of a website. While technically possible, scraping Google Trends can be challenging as the site uses dynamic content and limits how many requests one can make in a certain timeframe. Moreover, web scraping is usually explicitly forbidden by the Terms of Service (ToS) of major online platforms. Instead, these platforms usually make available a so-called Application Programming Interface (API), a set of methods that allow the exchange of data between their servers and external applications. Whereas Google provides APIs for many of its services, to date there it does not offer a public API for Google Trends.[1]

In March 2024, in an effort to overcome this obstacle, we submitted a request to Google under the EU's Digital Services Act (DSA), which mandates that large platforms share the data they collect with research projects that serve the public good. This request granted us access to Google's private Trends API. Although in beta version, minimally documented, and likely not maintained, the API proved functional and delivered reliable results when compared to Google's public interface.

Two classes of data, linked to specific elements in the interface, proved particularly promising for our goals: *InterestOverTime* and *Top/RisingTopics*. *InterestOverTime* is a score related to the overall popularity of a search term in a specific region over time, while *TopTopics* and *RisingTopics* provide

[1] Pytrends is an unofficial API that interacts directly with Google's private endpoints, mimicking browser requests. Although this practice is generally considered less intrusive than traditional web scraping, it still operates in a legal grey area and remains vulnerable to disruptions if Google updates its backend systems. Another option would be that of purchasing data from third parties that claim to give access even to absolute search volumes. However, the services we explored do not generally provide a clear technical documentation of how they operate, and they did not answer our inquiries in this sense.

lists of the most popular topics and the most trending topics associated with a specific search term. Before explaining what these variables entail, it is useful to specify the notion of "search term" adopted in this context. It is possible to query Google Trends methods either for literal search terms (i.e., queries) or for abstract semantic entities (i.e., topics). We opted to collect our data based on the semantic entity "Sustainability" (ID in the Knowledge Representation graph: "/m/0hkst"), rather than constructing a list of literal search terms. This approach has the major advantage of capturing a number of queries with strong associations to sustainability, avoids the daunting task of compiling a comprehensive list of keywords and bypasses the issue of language-specificity of search queries.

2.1.1 The evolution of public attention towards sustainability: InterestOverTime

InterestOverTime provides the evolution of the relative popularity of a search term in a certain combination of timeframe and location (Figure 1). This measure does not correspond to the absolute volume of Google searches for a specific topic, but is a relative score that indicates how searched a certain term was in relation to all the searches in the specified region at the time. This score is obtained "calculating the total number of searches for a specific search term relative to the total number of searches in each location and at each time period" (Zepecki et al. 2020). We suggest that *InterestOverTime* can be interpreted as a measure of the relative attention that the public gave towards a certain issue as compared to all other issues that were searched on Google at that time and place.

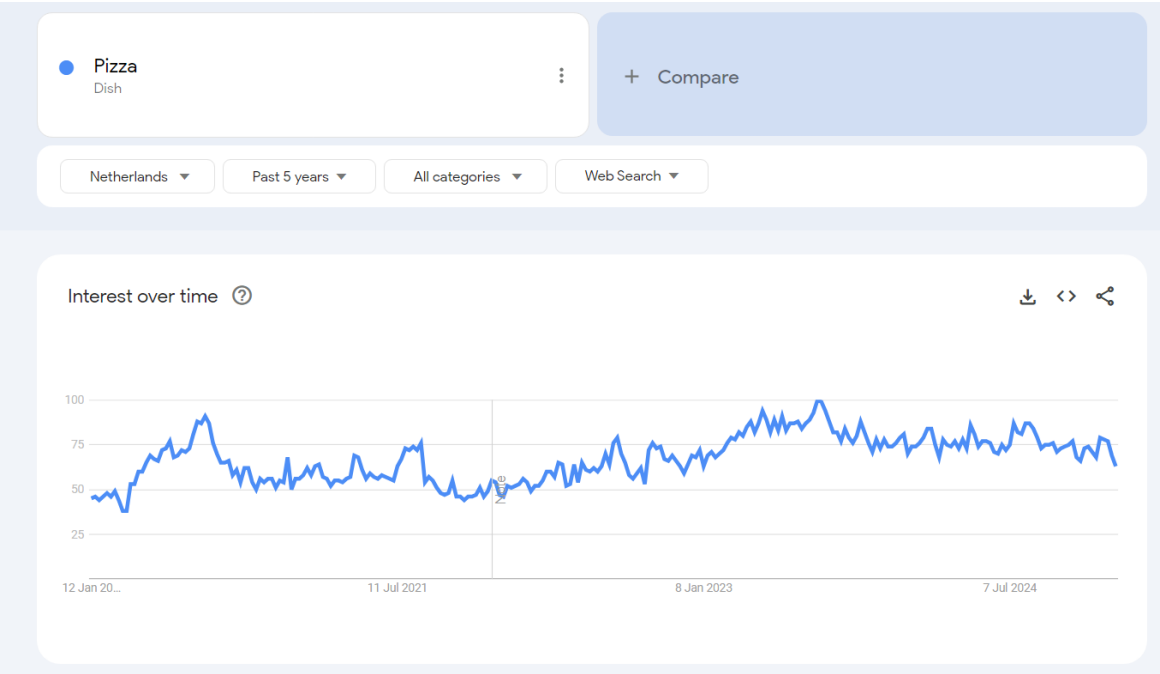

Figure 1 - Google Trends interface showing the IntererstOverTime for the semantic entity "Pizza" (source: Pizza - Explore - Google Trends).

The standard *InterestOverTime* measurement, as accessible through the interface or through the method *getGraph* in the Trends API, is a timeseries of scores normalized between 0 and 100, where a higher score indicates a higher search frequency relative to all other searches within the specified temporal and spatial boundaries. Each timeseries is given within a certain timeframe (with the earliest data from 2004), with a certain time resolution (day, week, month, year), and, optionally, restricted to a specific location (worldwide, country or province).

The fact that the score is normalized within each query affects the possibility of comparisons across queries. On the one hand, the normalization allows for a comparison of relative search frequencies between regions of varying populations and internet penetration. On the other hand, it places major limitations on the analytical potential beyond Google's pre-defined spatial and regional categories. For instance, as Europe is not a pre-defined regional category, it is not possible to calculate the *InterestOverTime* for a search term across the continent, although each European country has its own relative score.

However, Google's Trends API offers an alternative method (*getTimelinesForHealth*) which gives access to a different version of the score, originally developed to provide a more advanced level of access to health researchers. Since it was not possible to obtain an official confirmation of the meaning of such score, we conducted a series of comparisons between the standard *InterestOverTime*, as retrieved through the interface, and *getTimelinesForHealth* (see Appendix I). These tests suggest that Health data are, despite minor divergences,[2] the non-normalized version of the standard data obtainable through the interface or through the API. Crucially for our analyses, we also directly tested that Health *InterestOverTime* data produce the same cross-country rankings displayed in the interface, meaning that the comparative claims made by Google on the documentation of the interface (Figure 2) can be safely transferred to Health data.[3]

[2] Although additional analysis did not reveal the cause of these discrepancies, their magnitude is sufficiently small to ensure that the conclusions drawn from both datasets remain consistent.

[3] We observed a suspiciously high amount of zero values assigned to *InterestOverTime* in specific countries– steadily declining (see Appendix II). Despite the ambiguous formulation provided by the interface ("0 means that there was not enough data") could suggest that 0 values are to be treated as missing data, the Google Trends Help Center page (Google, n.d.) clarifies that "search terms with low volume appear as 0". This approximation introduces a distortion when aggregating or averaging data, as it excludes "low" values of *InterestOverTime*. However, it is unlikely to significantly distort the interpretation of the results, given that it merely rounds down already low values.

Figure 2 - Google Trends' interface comparing InterestOverTime value across countries (source: Pizza - Explore - Google Trends).

We proceeded collecting *InterestOverTime* data as follows. For each of the 27 EU countries, we used the *getTimelinesForHealth* API method to retrieve the non-normalized *InterestOverTime* for the semantic entity "Sustainability" for each week since 2004. This dataset allows us to analyse the temporal evolution and the geographical distribution of the public attention towards the issue of sustainability, as manifested by the (relative) volume of Google searches.

2.1.2 Bottom-up associations to sustainability: Top/RisingTopics

TopTopics is a list of the most popular topics associated with a specific search term in a certain timeframe. Conversely, *RisingTopics* is a list of topics associated with a specific search term that have shown the highest rise in popularity compared to the previous timeframe. For both *TopTopics* and *RisingTopics* up to 25 topics are compiled per search term. The association between the topics in these lists and the search term is based on which topics are most frequently searched together with the search term within the same search session.[4] Consequently, we can interpret *TopTopics* and *RisingTopics* as a tool to explore the associations that users attribute to a certain issue from the bottom up– *TopTopics* focusing on more stable patterns of popularity, while *RisingTopic*s focusing on more contingent spikes of interest.

TopTopics and *RisingTopics* are lists of semantic entities extracted by Google from users' literal queries, based on its proprietary Machine Learning algorithms and its Knowledge Representation Graph. It is also possible to collect TopQueries and RisingQueries, analogous data that consists of the most popular and most trending literal queries associated with a search term. TopQueries and RisingQueries represent potentially interesting resources, as they allow us to have a more nuanced understanding of what users associate with a certain issue. However, literal queries introduce evident challenges of inconsistency and language-specificity, thus requiring a certain level of uniformation and classification. Consequently, we opted to focus on *TopTopics* and *RisingTopics*

[4] See https://support.google.com/trends/answer/4355000.

and thus rely on Google's own semantic classification strategy – black-boxed, but ready-made. After a first round of analysis, it became clear that this semantic classification strategy presents a certain degree of inconsistency, most crucially in the form of pseudo-synonymous entities classified as separate entities. For this reason, we consolidated the topics retrieved, merging semantically highly contiguous entities (see Repository). For this purpose we used OpenRefine, an open-source tool for data cleaning, enhanced by a cursory manual inspection. This refined version of *TopTopics* and *RisingTopics* was used for the analysis, in order to avoid misleading statistics associated with very similar entities (e.g., Sustainable Tourism and Tourism; Natural Environment and Environment) counted as separate ones.[5]

We proceeded collecting *TopTopics* and *RisingTopics* data as follows. For each of the 27 EU countries, we pulled the *getTopTopics* and *getRisingTopics* API method, to retrieve the *TopTopics* and *RisingTopics* related to the semantic entity "Sustainability" for each month since 2004. After consolidation, the datasets consisted in 751 unique *TopTopics* and in 2150 unique *RisingTopics*. These datasets allow us to analyse the spontaneous, bottom-up associations that users make in relation to sustainability over time.

[5] It must be acknowledged that this process of semantic consolidation has an inherent arbitrary component, since it is impossible to neatly identify and coherently apply a cut-off point between semantically contiguous and not contiguous entities (e.g., are Climate and Climate Change the same topic?); and a different approach to topic consolidation could provide more or less significantly different results due to its impact on topics' frequency.

3. Data Analysis

In analysing the data we relied on descriptive statistics and visualization, following the principles of exploratory data analysis (Tukey 1977). It is worth mentioning that what follows is only a selection of the analytical possibilities afforded by this data, considering the number of trade-offs we encountered in the process. In the Conclusions, we offer suggestions for further analyses.

Despite having collected data since 2004, we decided to restrict the timeframe of our analysis further. Besides dropping the current year (2024), since it would provide incomplete data, we also decided to restrict the starting date for the analyses to 2013. From a preliminary inspection of both datasets, it became clear that the lower total search volume associated with previous years could introduce substantial distortions, such as a high number of "zero values", anomalous "peaks" in the *InterestOverTimelow* and significantly lower numbers of topics retrieved (see Appendix II).

In the Trend Analysis section we present the results of the analysis of *InterestOverTime* data, both from a longitudinal and cross-country perspective, answering RQ1. In this section we answer the following specific research questions:

- RQ1.1: How does the attention towards sustainability evolve over time in the EU?
- RQ1.2: How does the attention towards sustainability evolve in each EU country?
- RQ1.3: How is the attention towards sustainability distributed among EU countries?
- RQ1.4: How does the ranking of EU countries in terms of attention to sustainability evolve over time?

In the Topic Analysis section we present the results of the analysis of *Top/RisingTopics* data, addressing RQ2. As mentioned earlier, the results of *TopTopics* and *RisingTopics* are presented in parallel, since both datasets can lead to interesting, albeit different interpretations. In this section, for each dataset, we answer the following specific research questions:

- RQ2.1: What are the topics most frequently associated with sustainability in the EU?
- RQ2.2: How do the topics most frequently associated with sustainability in the EU evolve over time?
- RQ2.3: What are the topics most frequently associated with sustainability in each EU country?
- RQ2.4: How (strongly) do EU countries cluster together in terms of topics associated with sustainability?

4. Results

4.1 Trends Analysis

In this section we focus on the variable *InterestOverTime*, in order to explore which insights Google Trends data can give us in terms of the dynamics of attention towards sustainability, operationalized through a measure of the relative volume of Google searches.

RQ1.1 - How does the attention towards sustainability evolve over time in the EU?

Figure 3 plots the evolution of *InterestOverTime* for the topic Sustainability. For each time point, the values are averaged among EU countries, in order to have an idea of the overall trend. Whereas the absolute value of this score is not meaningful per se, its evolution is related to public attention's dynamics.

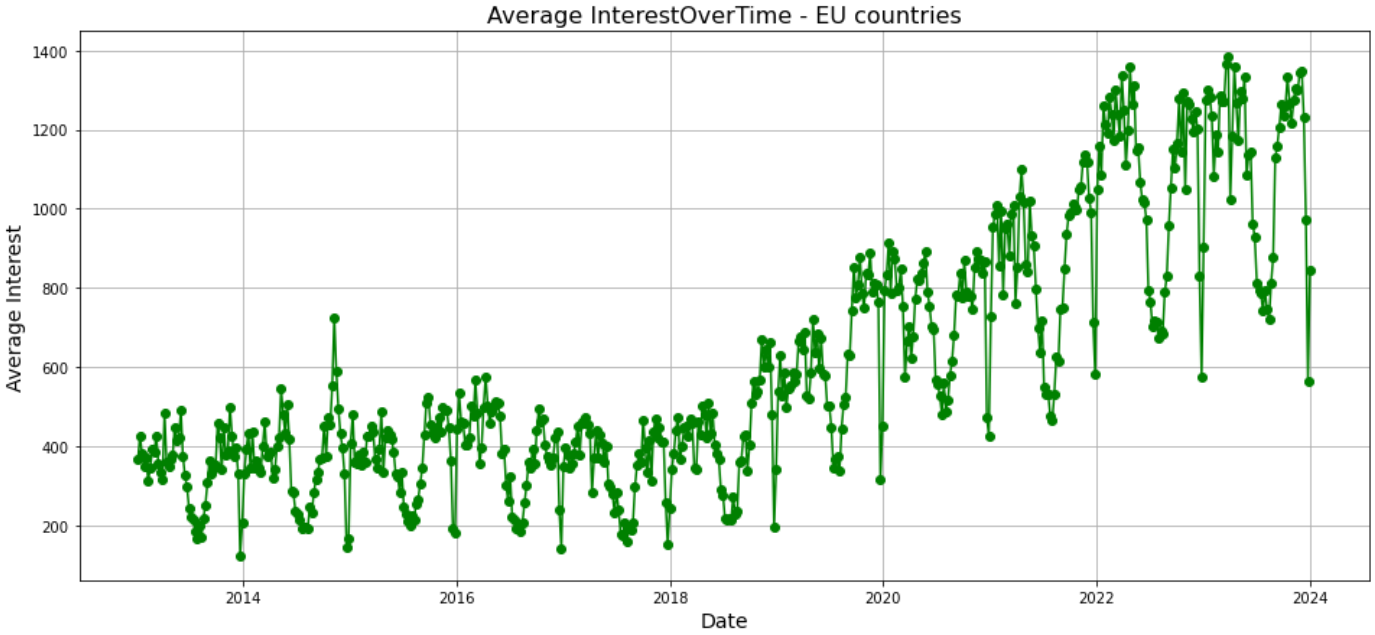

Figure 3 - Evolution of InterestOverTime, topic "Sustainability", average among EU countries, 2013-2023.

We can observe evident within-year fluctuations, which at closer inspection appear clearly related to seasonality: the dips always correspond to summer and winter holiday time, where we can expect the interest towards sustainability to drop. More interestingly, it is clear how the average *InterestOverTime* in the EU has been almost invariant between 2013 and 2017 (oscillating between 342 and 390), and started a steady growth from 2018, increasing almost linearly from 344 to 1122.

RQ1.2: How does the attention towards sustainability evolve in each EU country?

The line graph above can be decomposed to visualize each country's trend (Figure 5). However, the heatmap in Figure 4 clearly illustrates the dynamics of *InterestOverTime* in each country. Values are normalized within each country in order to let the trend within the country emerge, rather than focusing on cross-countries comparison. This means that the visualization should be read horizontally. The darker the colour of the cell, the higher the value of *InterestOverTime* for that country in the 10 years distribution.

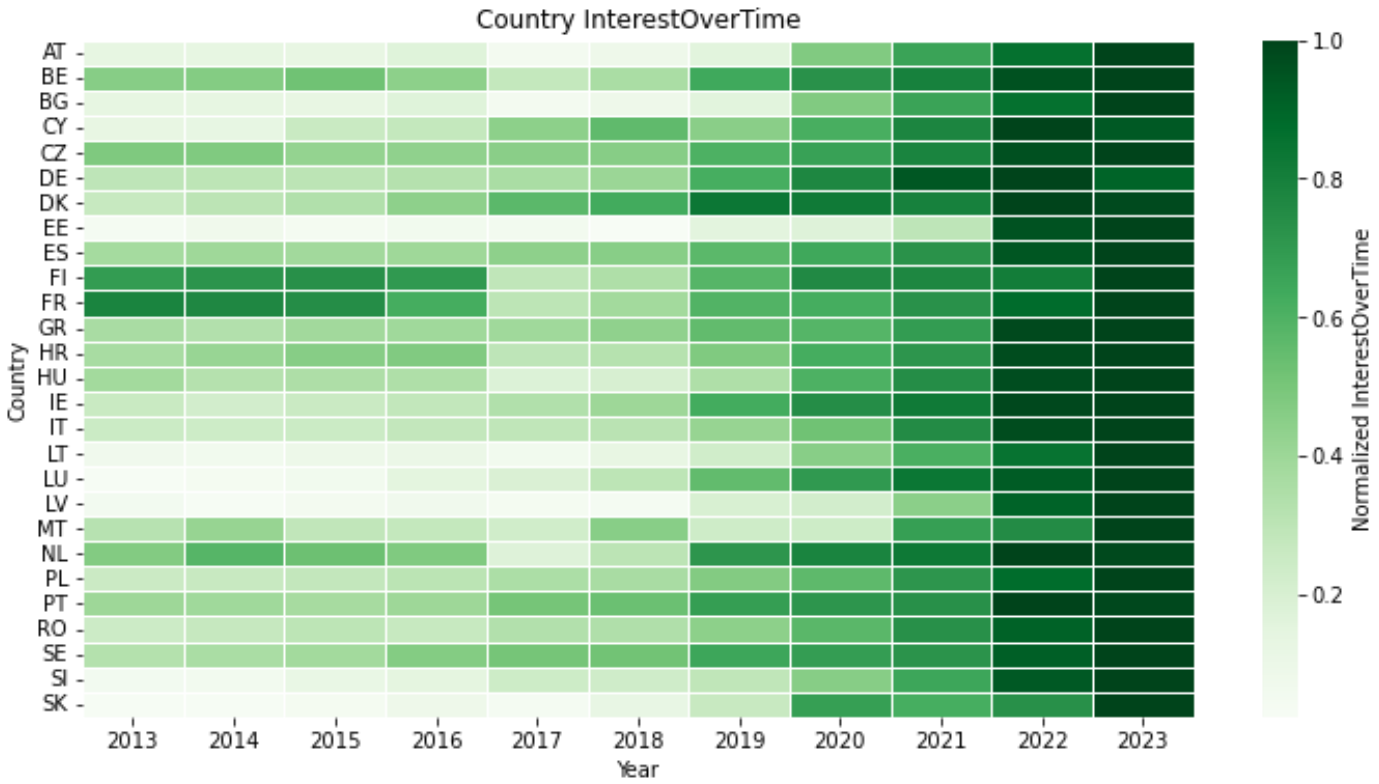

Figure 4 - Evolution of InterestOverTime for topic "Sustainability" across individual EU countries, normalized within countries, 2013-2023.

We can observe how, coherent with the average trend, the *InterestOverTime* follows a monotonic growth in most countries, with the interesting exception of countries following a U-shaped trend. For those countries, such as France and Finland, the relative volume of searches related to sustainability manifests a dip in the central years of the distribution, in contrast with the general trend, before starting to increase again.

RQ1.3: How is the attention towards sustainability distributed among EU countries?

Turning to the distribution of *InterestOverTime* across countries, Figure 5 plots the average value across the timeframe for each EU country, sorted in descending order.

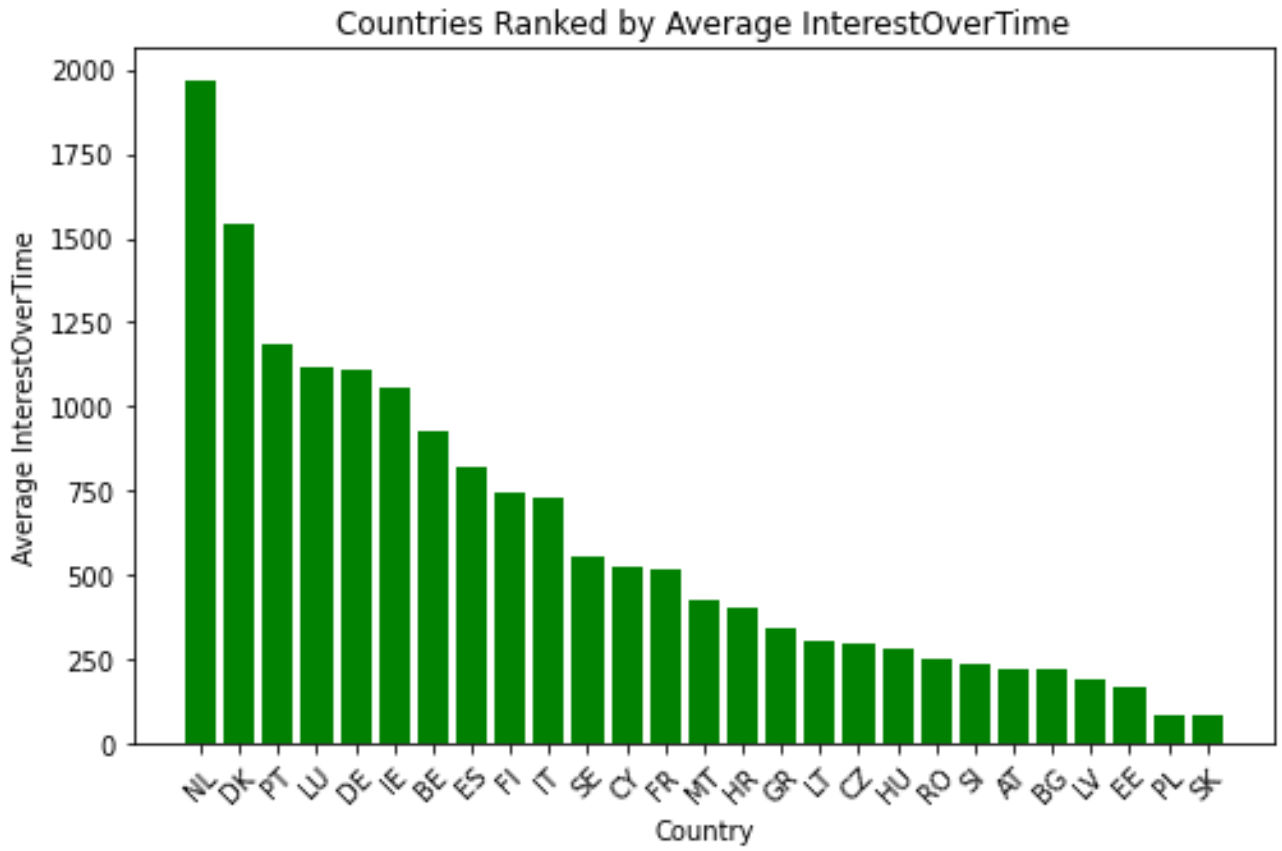

Figure 5 - Distribution of InterestOverTime for topic "Sustainability" across EU countries, average over 2013-2023.

The Netherlands and Denmark are by far the countries with the highest relative share of Google searches related to sustainability, with values approximately 3 times the average and approximately 20 times the lowest values presented by Slovakia and Poland. Scanning the ranking it is quite evident that the distribution follows a Western Europe vs. Eastern Europe cleavage, with the notable exception of Austria which presents a very low value despite being mainly associated with Western Europe in a cultural and political sense.

RQ1.4: How does the ranking of EU countries in terms of attention to sustainability evolve over time?

In Figure 6, the evolution of the normalized *InterestOverTime* was plotted. However, this does not give us information about how the score co-evolves across countries. To observe this, we computed the yearly ranking among countries, and plotted the evolution of the rankings in a heatmap (Figure 6). The heatmap can be read vertically in order to trace each early ranking; and it can be read horizontally in order to observe the stability of a country's position in the ranking. A darker colour implies a higher position in the ranking. In other words, this visualization allows us to infer how much attention a country has been given to sustainability compared to the other countries.

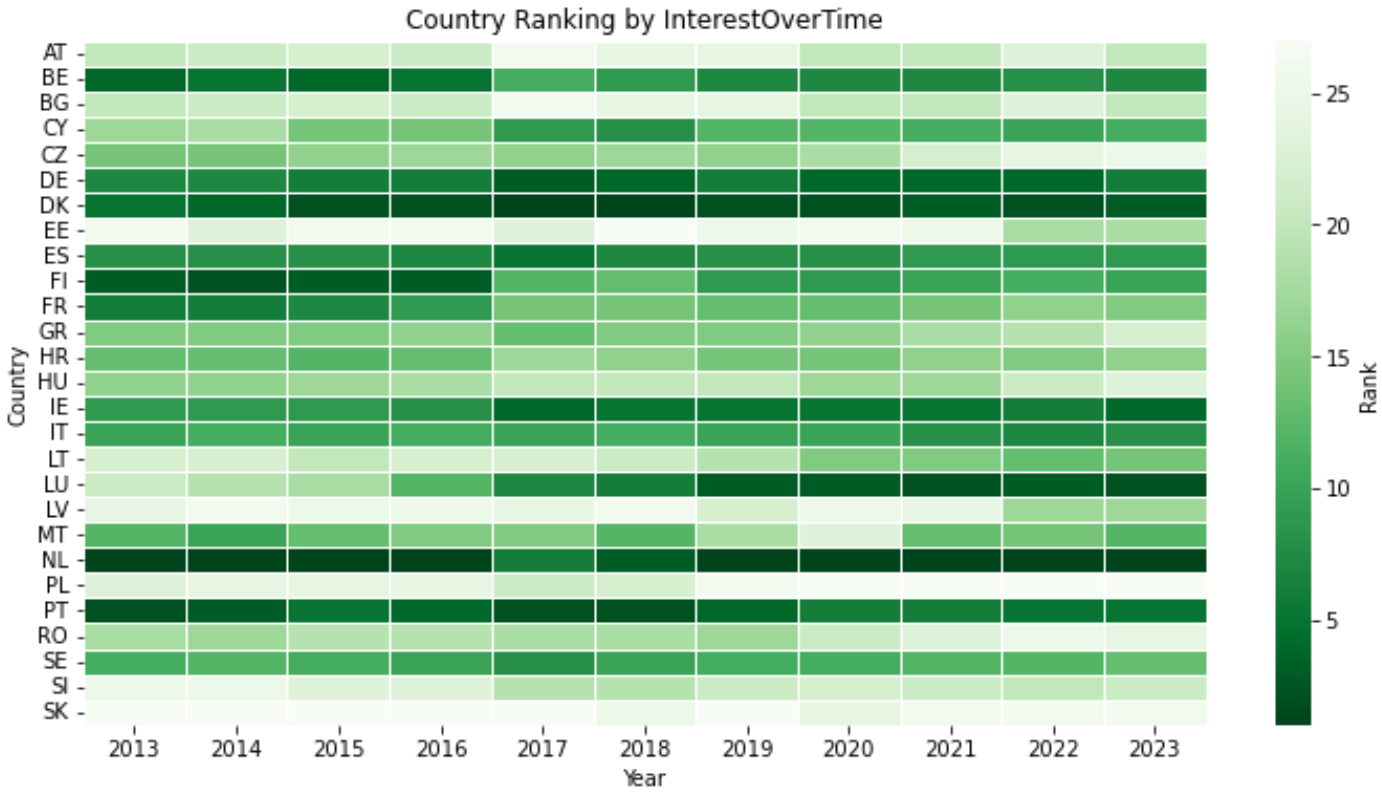

Figure 6 - Evolution of country ranking based on InterestOverTime of topic sustainability, EU countries, 2013-2023.

By comparing the evolution of the columns, we can see how the ranking tend to be fairly stable across countries, with few exceptions: France, losing positions since 2016; Estonia, Lithuania, Luxemburg and Latvia, more or less steadily increasing in ranking; Austria, Finland and Belgium showing a dip somewhere between 2017-2018/2019.

4.2 Topic Analysis

In this section we present the results of the analysis of *TopTopics* and *RisingTopics*. These are topics that, for each EU country and in each month between 2013 and 2023, have been frequently searched for by users together with the topic "Sustainability". For these reasons they can be operationalized as a proxy to explore grassroots associations to sustainability and their evolution over time. *TopTopics* refer to the most popular, hence stable associations, while *RisingTopics* refer to the most trending, hence more volatile ones. Since they both provide relevant insights into the composition and dynamic of public attention towards sustainability, they are presented in parallel. It is important to remember that the list of topics provided by the API, based on Google's semantic parsing of users' queries, has been subject to a preliminary process of refinement and low-level consolidation to avoid obvious duplications, and the results might be sensitive to alternative logic of aggregation.

RQ2.1: What are the topics most frequently associated with sustainability in the EU?

Table 1 lists the 50 most recurrent *TopTopics*. These correspond to the most popular topics associated with sustainability by users' activity on Google, each month for each EU country. The frequency distribution is very skewed, with the top 50 topics covering approximately 85% of the total occurrences.

#	Topic	Count
1	Energy	3552
2	Sustainable development	3497
3	Report	3307
4	Tourism	3066
5	Environment	3044
6	Economic development	2890
7	Economy	2392
8	Sustainable Development Goal	2378
9	Management	2209
10	Fashion	2193
11	Company	1633
12	Agriculture	1569
13	Ecosystem	1430
14	Strategy	1413
15	Business	1382
16	Project	1253
17	Goal	1237
18	Definition	1221
19	Finance	1153
20	United Nations	1116
21	European Union	1022
22	Building	1008
23	Education	939
24	Design	827
25	Investment	761

#	Topic	Count
26	Corporate social responsibility	757
27	Climate	757
28	Europe	631
29	Brand	623
30	Architecture	565
31	Industry	561
32	City	539
33	Technology	512
34	Product	496
35	Transport	486
36	Renewable resource	482
37	System	480
38	University	443
39	Innovation	435
40	Social	378
41	Clothing	361
42	Year	348
43	Research and development	334
44	Investment fund	333
45	International development	330
46	Production	310
47	Plan	280
48	Science	271
49	Society	270
50	Environmental, social, and govern	265

Table 1 - Most popular topics per month (TopTopics) frequently associated with sustainability in EU countries, 2013-2023.

A cursory inspection of the list suggests a number of key-points. The theme of Energy is the most searched, underscoring its centrality within Google searches related to sustainability. Unsurprisingly, the rather generic theme of Sustainable Development follows immediately for popularity. Report is also on top of the list, likely due to periodic changes in reporting frameworks, followed by a number of other topics underscoring a "pragmatic" approach to sustainability, linked to an organizational dimension (e.g., Management, Strategy, Project). A number of other highly occurring, more or less generic topics (namely Economic development, Economy, Company, Business, Finance, Investment, CSR, Brand, Investment fund, Production) suggest that sustainability is largely conceptualized from an economic, financial and corporate angle where specific economic sectors emerge, specifically Tourism, Fashion, Agriculture as particularly popular. The theme of natural environment is also well represented, with the generic topic Environment among the most frequent, alongside Ecosystem and Climate further down the list. Other fundamental themes, such as the social, educational, political and technological dimension of sustainability are present, but are less dominant.

Table 2, conversely, presents analogous results in terms of *RisingTopics*. These correspond to the topics that, regardless of their initial relevance, have suddenly increased in relative search volume. In this case, given their higher volatility, the distribution is less skewed, with the top 50 topics accounting for approximately 40% of the total topics.

#	Topic	Count
1	Tourism	900
2	Company	805
3	Energy	697
4	Economy	662
5	Education	661
6	Economic development	652
7	Building	616
8	Report	604
9	Year	564
10	Agriculture	553
11	University	529
12	Management	528
13	Business	515
14	Environment	514
15	Architecture	506
16	Fashion	503
17	Design	437
18	Sustainable Development Goal	413
19	Consumerism	395
20	Ecosystem	387
21	Strategy	366
22	Innovation	354
23	Transport	350
24	Supply chain	344
25	Finance	344

#	Topic	Count
26	City	343
27	Technology	337
28	European Union	336
29	Renewable resource	335
30	Goal	322
31	Academic journal	318
32	Sustainable development	310
33	Resource	303
34	Industry	301
35	Project	300
36	Science	298
37	Investment	297
38	Brand	294
39	Product	284
40	Production	283
41	Definition	280
42	Waste	276
43	United Nations	267
44	Engineering	267
45	Policy	266
46	Research and development	258
47	Society	253
48	Climate	253
48	Plan	246
49	Packaging and labeling	245

Table 2 - Most rapidly growing topics per month (RisingTopics) frequently associated with sustainability in EU countries, 2013-2023.

A comparison of the two lists shows that the most frequent *Top Topics* and the *Rising Topics* largely overlap. Nonetheless, the ranking presents some important differences. For *Rising Topics*, Tourism leads the ranking, which could be linked to the seasonality of the trends observed in the previous section. Conversely, the pragmatic/organizational dimension is less prominent, suggesting that this relates to a persistent and stable use of the search engine. Whereas Energy and economic factors seem still prevalent, the theme of education is somewhat better represented (with Education in the top 5, and other topics such as University and Academic Journal).

RQ2.2: How do the topics most frequently associated with sustainability in the EU evolve over time?

The following heatmap (Figure 7) plots the evolution of the ranking of *Top Topics* over time. It provides an overview on the dynamics of the most popular associations that users establish between sustainability and other topics. We limited the topics considered to the 15 most recurrent each year. The intensity of the cell's colour is proportional to the frequency of each topic in that year. Since the values are not normalized, the heatmap can be interpreted both horizontally and vertically. When inspected horizontally, one can gauge the evolution of the popularity of each topic. When inspected vertically, one can evaluate which topics have been the most popular each year. For the generalistic and synthetic purposes of this section, we opted to focus on the latter, thus commenting on the evolution of the topics.

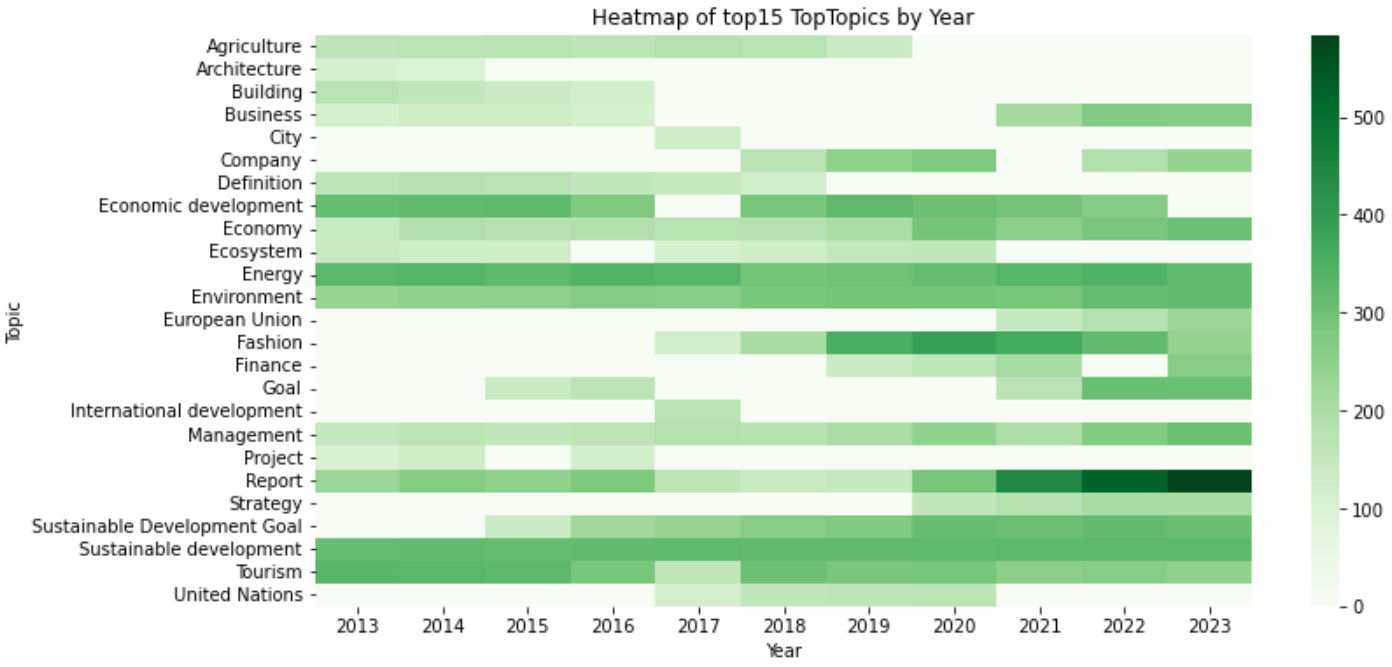

Figure 7 - Evolution of most recurrent Top Topics over the years, EU countries 2013-2023.

Inspecting the visualization leads to a couple of observations. Throughout the years, there are a few topics that are consistently among the most associated with sustainability by Google users, namely Sustainable development, Tourism, Economy, Energy and Environment. Report, Sustainable Development Goal, Strategy and Fashion are examples of topics that rose to prominence over the years, while Agriculture, Definition and Project manifest a clear decline. A couple of topics rose and declined over the timeframe, specifically United Nations and International Development. Conversely, Business is a topic that presents a dip in the middle of the timeframe.

Figure 8 replicates the same map, but with *RisingTopics* data. Instead of showing the evolution of the most popular topic, it shows which topics have suddenly risen in popularity over the years.

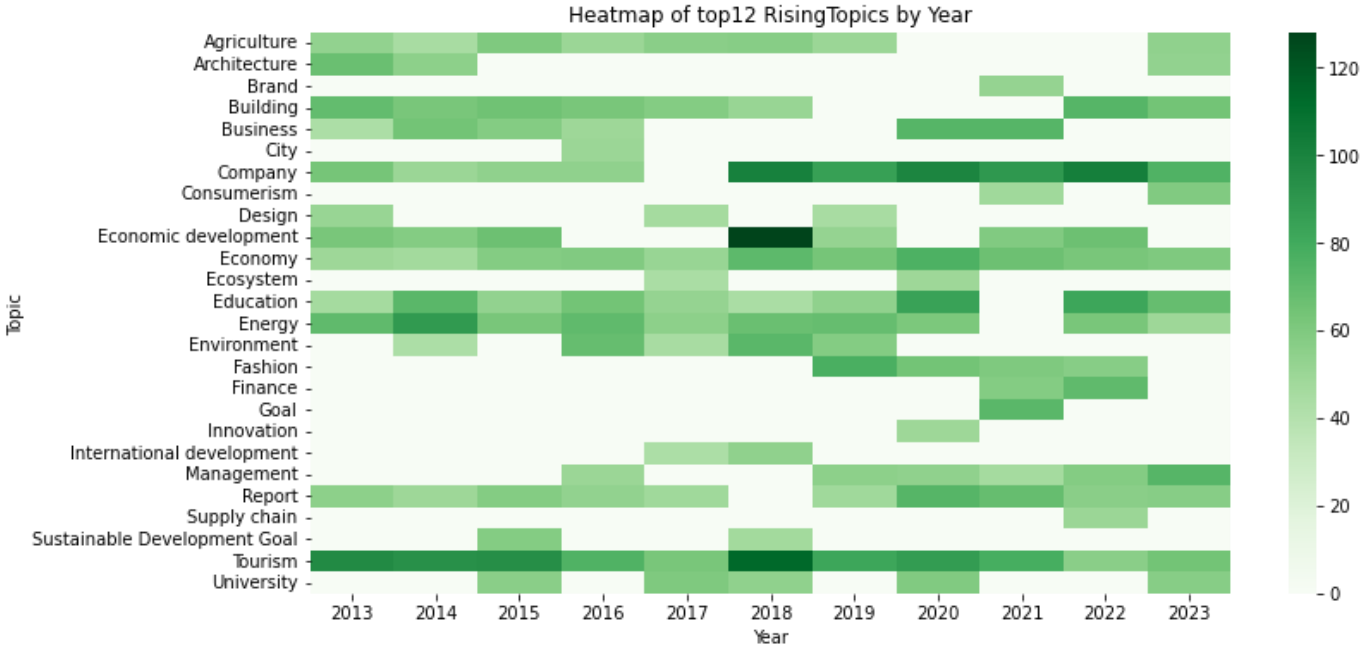

Figure 8 - Evolution of most recurrent RisingTopics over the years, EU countries 2013-2023.

Coherently with their more contingent nature, the dynamic of *RisingTopics* seems less linear than in the case of *TopTopics*. Tourism is one of the topics consistently related to monthly spikes in attention, likely because of the seasonal nature of the interest towards the issue. An analogous consideration could apply to Report. Sustainable Development Goal rose in prominence in 2015, the year in which they were launched, and in 2018.

RQ2.3: What are the topics most frequently associated with sustainability in each EU country?

It is also informative to unpack which topics are most frequently associated in which specific countries. The heatmap below (Figure 9) visualizes the distribution of the occurrence of a set of *TopTopics* in each EU country. For the sake of readability, the list of topics was restricted by including only the 10 most occurring topics in each country.[6] The darker the cell, the more frequently the correspondent topic has been associated with that country. The heatmap can be read horizontally, to identify in which countries a specific topic has been more frequently searched for; or it can be inspected vertically, to discover which topics have been more prominent in each country. For the general purpose of exploring the insights afforded by this data, we decide to focus here on a vertical, topic-based reading.

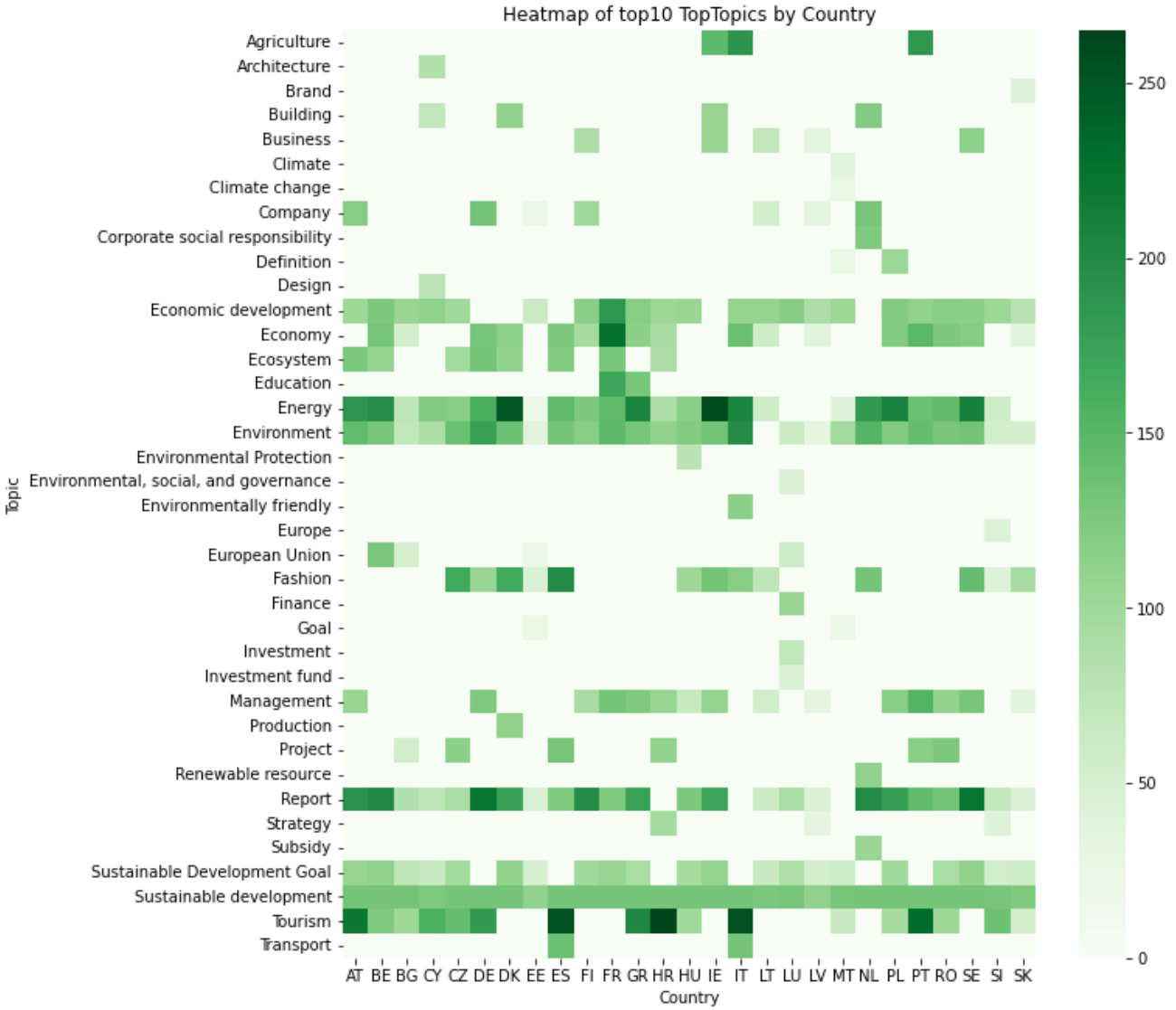

Figure 9 - Association between countries and most recurrent TopTopics, EU countries 2013-2023.

[6] Inspecting the full lists can provide other insights (see Repository: TopTopics_count_by_year.csv and RisingTopic_count_by_year.cs).

The inspection of the matrix leads to a few inferences. A limited number of topics associated with sustainability in Google searches have a more generalistic character, while many are specific to a few countries. Sustainable Development is the only topic almost equally distributed among all the 27 countries. Environment is also comparatively well spread out; however, it is stronger in countries like Italy and Germany, while less prevalent in the Baltic countries. Energy is recurrent in many countries, but with important differences: Ireland is by far the most associated country, while it is searched very rarely in Luxemburg, Slovakia, Malta and, again, the Baltics. Tourism is quite consistently featured in the *TopTopics* of countries with a strong touristic vocation (Croatia, Italy, Portugal, Spain, Greece, Austria). Moving to topics that are consistently the most searched for in specific countries, noteworthy examples include Agriculture, relevant in Italy, Portugal and Ireland – an association that does not seem to reflect their ranking for contribution of the sector to the national economy. The topic of Education is prominent in France and Greece. Transport has been frequently associated with sustainability in Italy and Spain. Despite the low absolute values, it is interesting to notice how Design and Architecture are exclusively associated with Cyprus, and Investment with Luxembourg. Some topics are halfway between being generalistic and being country-specific. For example, Fashion is relevant for about half of the countries, but particularly relevant for Spain, Denmark and Czech Republic.

Figure 10 proposes the same visualization, but related to RisingTopics. The number of topics selected per country was restricted to the top 7, since the country-topics relations are more diversified and hence the list of topics selected was difficult to read.

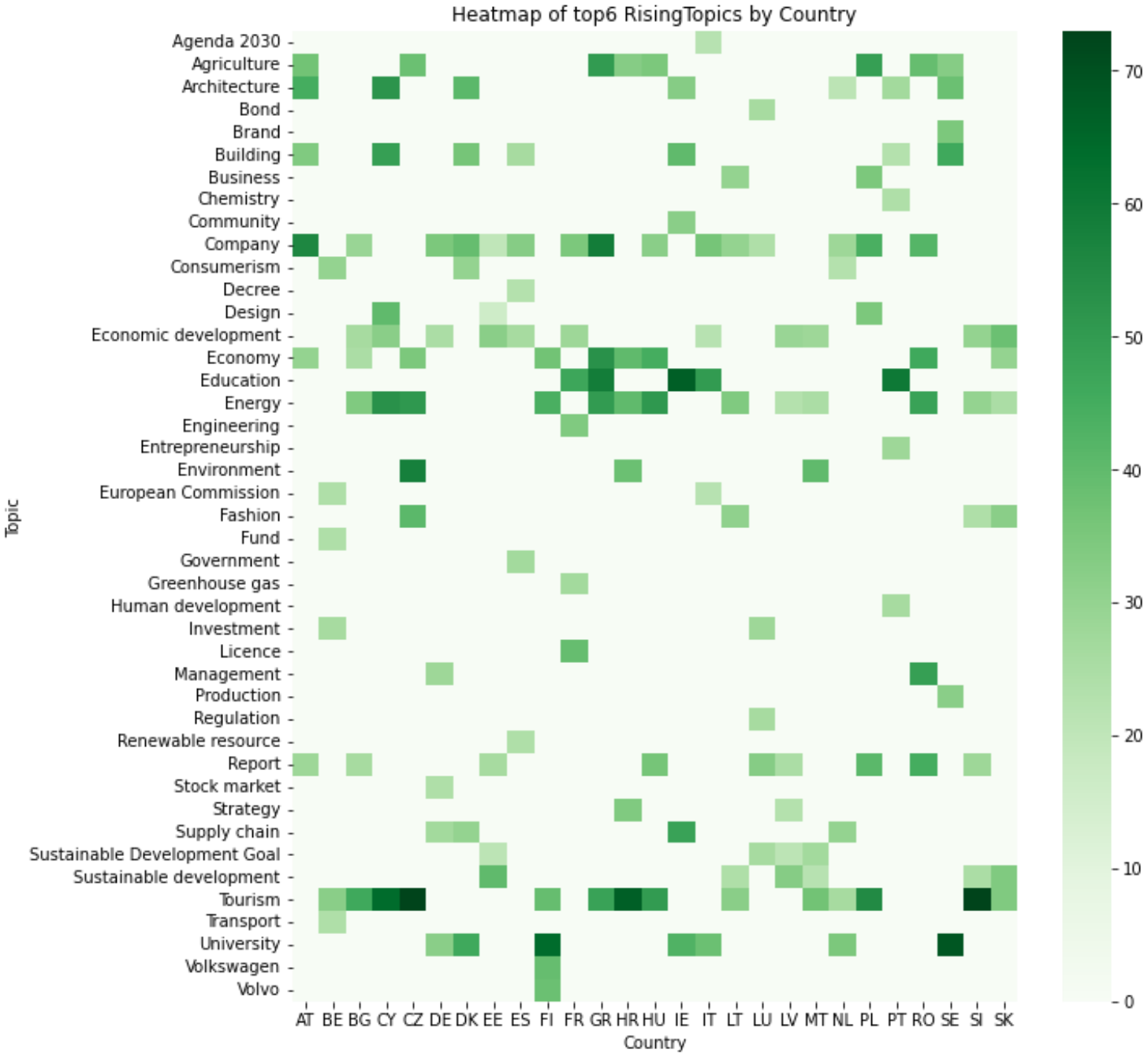

Figure 10 - Association between countries and most recurrent RisingTopics, EU countries 2013-2023.

The association between countries and *RisingTopics* reflects the highest volatility of this type of topics, as no topic is consistently frequently associated with all EU countries. A cursory comparison with the *TopTopics* associations suggests some significant differences. Agriculture has been trending more frequently in countries like Greece, Poland and Romania. Architecture remains relevant to Cyprus, but becomes strongly associated also to Austria, Denmark and Sweden. Similarly, Education maintains its prominence for France and Greece, but becomes strongly related to Ireland, Portugal and Italy. Chemistry is a topic trending in Portugal specifically. The association between

Consumerism and sustainability is frequently rising in Denmark, Belgium and the Netherlands. A curious emerging association is the one between Volvo and Volkswagen in Finland.

RQ2.4: How (strongly) do countries cluster together in terms of topics associated with sustainability?

Each month, users' search practices establish a connection between a country and a topic. These connections can be represented as a network graph in which countries are linked to a set of topics each month. This is what in network analysis is called a bipartite graph–a network where nodes belong to different classes, and edges are established only from one class to the other (in our case, from countries to topics). Bipartite graphs are often difficult to analyse and inspect. A common workaround involves using projected graphs. In this approach, a bipartite graph is transformed into a unipartite graph by retaining only one class of nodes (in our case countries). Edges between pairs of nodes in the retained class are created based on the number of shared nodes they are both connected to in the original bipartite graph. It is important to note that edges are weighted based on the number of topics shared between two countries throughout the months. We built a country-to-country projected graph for each month, and then aggregated the results into one composite graph. The graph has been visualized using ForceAtlas2 algorithm, which arranges the nodes in space in a way that more connected nodes tend to be closer to each other, and nodes with less connections are pushed to the periphery. The thickness of the edges is proportional to their weight.

Figure 11 represents the country-to-country projected graph, based on the pattern of *TopTopics* shared.

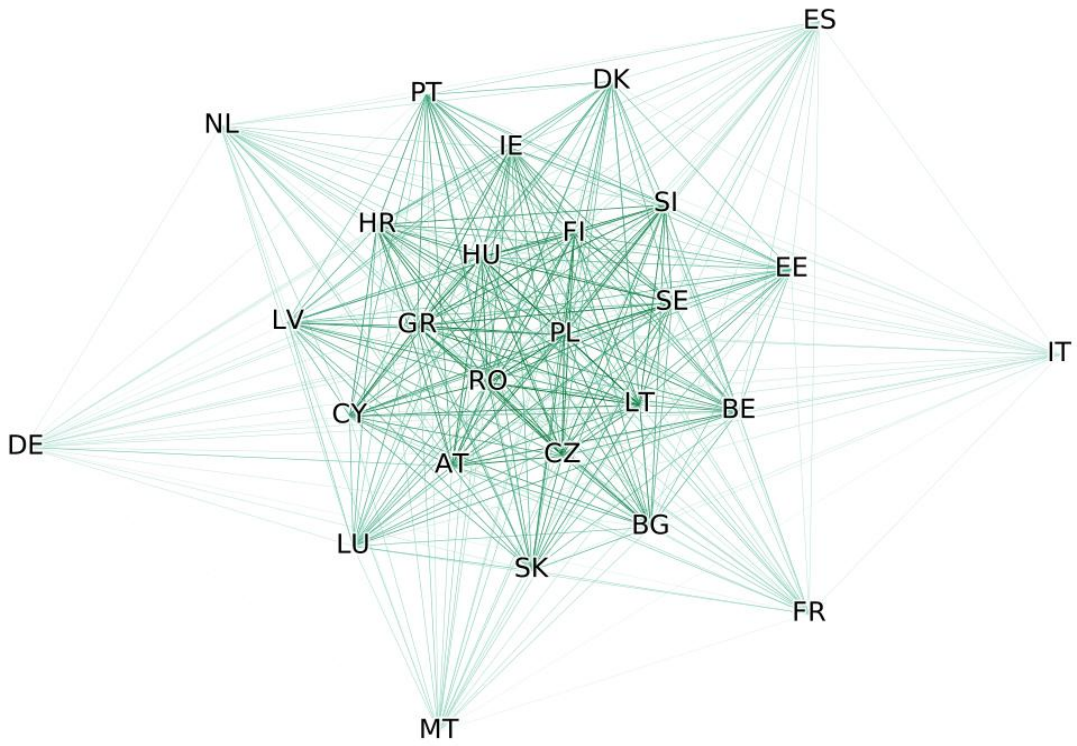

Figure 11 - Country-to-country network graph, projected from country-to-topic network graph, aggregation of monthly snapshots, TopTopics, EU countries 2013-2023.

The network graph is overall very connected and lacks a distinct modular structure that could reveal how groups of countries cluster together based on shared patterns of *TopTopics*.[7] It is interesting to notice a contrast between a few countries rather isolated in the periphery, and a core of countries positioned in the centre of the graph. This suggests that Italy, Germany, Malta, France and Spain are countries in which users tend to associate sustainability with more country-specific topics. It is not very interesting to comment on the most recurrent connections among countries, since the distribution of edges' weights is not very skewed (skewness=-0.07) and several pairs have comparable values (169 pairs in the range 96:70).

Figure 12 illustrates the country-to-country projected graph derived from the shared pattern of *RisingTopics*.[8]

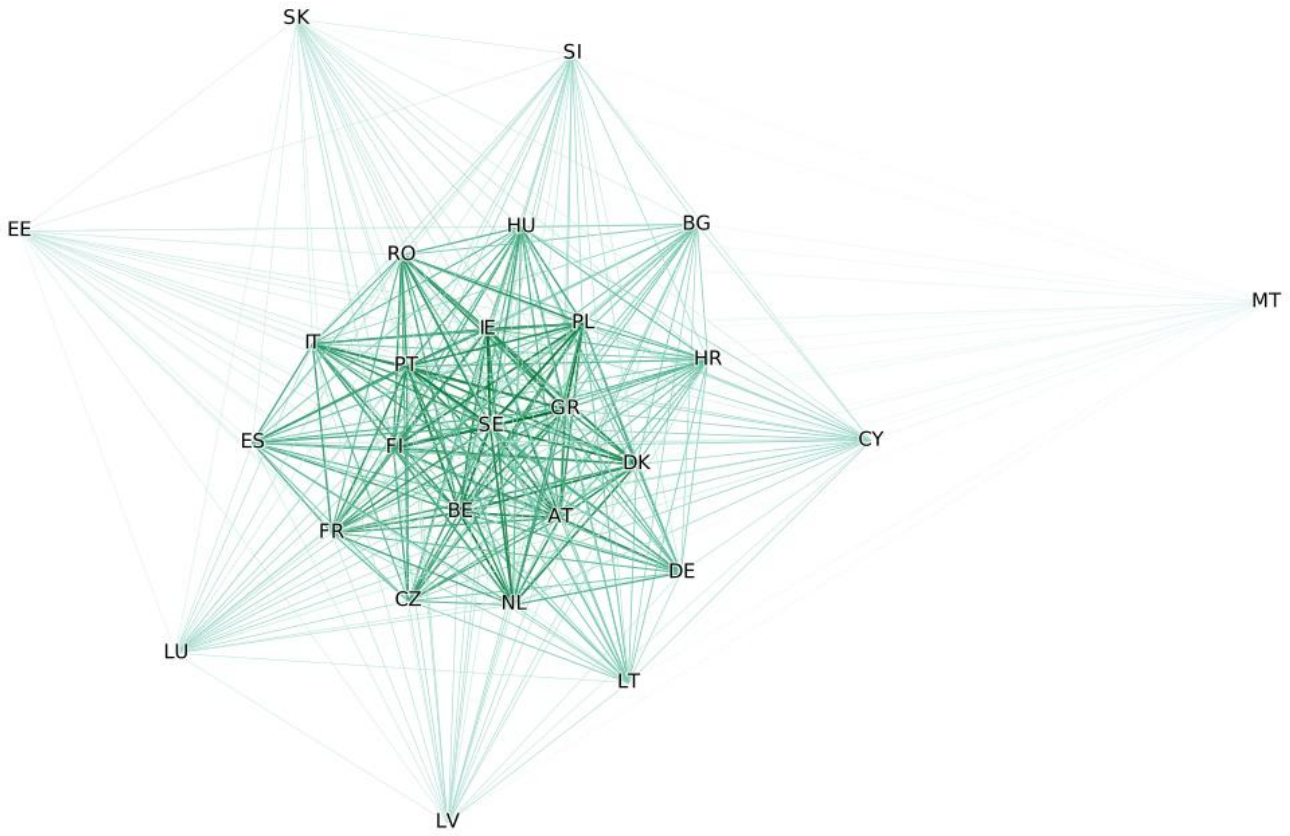

Figure 12 - Country-to-country network graph, projected from country-to-topic network graph, aggregation of monthly snapshots, RisingTopics, EU countries 2013-2023.

[7] The average modularity score, a measure of the tendency of network graphs to be structured in well-defined clusters, is extremely low (0.013), whereas values below 0.3 are generally interpreted as an indication of a lack of modular structure.

[8] The average modularity score, in this case, is higher but still very low (0.14).

Similar considerations apply to the *RisingTopic* version of the graph. The structure presents the same duality between highly connected and more isolated countries. In this case, however, the countries in which sustainability is more associated with country-specific issues, rather than issues shared with other EU countries, are Estonia, Slovakia, Slovenia, Luxemburg, Latvia, Lithuania, Cyprus and Malta. Again, no modular structure emerges, and the rather flat distribution of edges' weights make it irrelevant to investigate the most tightly connected countries.

5. Conclusions

This paper has served two main aims: firstly, to track the evolution of public attention to the concept of sustainability in Europe over the past ten years and secondly to propose a novel method for approaching research of public attention through Google Trends data. After summarizing the main findings of the research with regards to the research question, this section situates the findings within the context of current literature on sustainability, reflects on the main limitations with the proposed methodology, and outlines the analytical directions for future research.

We repurposed Google Trends data to study the dynamics and composition of public attention towards sustainability in the EU. Leveraging access to Google's private Trend API, we explored its analytical potential by focusing on two classes of data: *InterestOverTime* and *Top/ RisingTopics*.

Using *InterestOverTime* data, we analysed the longitudinal and cross-country distribution of public attention towards sustainability. We observe a steady growth of public attention towards sustainability since 2018. While most countries demonstrate a consistent increase in the attention given to the issue, France and Finland exhibit notable shifts. Furthermore, regional differences in overall attention towards sustainability are evident, with a clear divide between Western and Eastern European countries as seen in Figure 6. Western countries, particularly the Netherlands and Denmark, devote significantly more attention to the topic of sustainability as compared to other search queries, while Eastern European countries show markedly lower search frequencies. This ranking is mostly stable across the year, signalling a systematic unbalance. Nevertheless, the fact that all researched countries show their highest *InterestOverTime* in either 2022 or 2023 suggests an increased attention to the topic of sustainability over time, despite a East/West divide. Such an increase to public attention aligns with the developments outlined by other sustainability and media research which shows that the topic of sustainability has gained increasing focus both in news reporting (Hase et al., 2021), governance (Bosi et al., 2022), and corporate management (Coelho et al., 2023).

With *Top/RisingTopics* data, we further identified the topics most prominently associated with the concept of sustainability from the bottom-up and we examined patterns of connections between countries and topics. This analysis reveals the prominence of a few general themes that are frequently associated with sustainability across both countries and time, such as Energy, Sustainable Development, and Environment. However, the prominence of economic and corporate-related topics such as Report and Management also suggests that sustainability is often framed through an organizational and economic lens, an aspect that does not emerge in the current literature. The increased searches for "sustainability report" most likely corresponds to the increased demands for companies and corporations to conduct sustainability reports within their organizations, which naturally directs employees attention to the topic of sustainability in their daily lives although it does not make it to any news headlines.

The distribution of topics across countries reveals how the most recurrent themes are generally well spread out, while a few topics reflect more specific associations (such as Architecture in Cyprus, Education in France and Greece, and Investment in Luxembourg). Countries are also not clustered in recognizable patterns based on shared associations to sustainability. While many countries are closely linked among each other, signalling that they often share the same topics, a few countries manifest more country-specific patterns of associations. This duality suggests varying levels of integration among countries in terms of emerging associations towards sustainability. Furthermore, emerging themes like Fashion, and declining ones like Agriculture, point to a dynamic evolution of the semantic associations to sustainability. These findings not only underscores Hajian and Kashani's (2021) argument that the concept of sustainability is continuously expanding and changing to encompass a multitude of aspects relevant to a specific time and space but also highlights the relevance of adopting a framework of sustainability that acknowledges the interdependent nature of these aspects, as suggested by Biggeri et al. (2024).

5.1 Limitations

We interpreted Google Trends data as a proxy for public attention towards sustainability. This conceptualization draws a direct parallel between people's Google search practices and the general public opinion dynamics. The limits of operationalizing a general concept ('the public') within a more specific one go beyond issues of statistical representativity. Not only the people using Google on a daily basis are not equivalent to the general population[9]; importantly, a search engine is used for specific purposes. For example, the fact that many topics are associated with economic and organisational factors might be explained by the relevance that the search engine plays in work settings. Because of this limitation, triangulation with other data sources becomes an important form of methodological validation.

A related issue refers to the fact that a score of relative search volume lacks context on the search practices from which it is computed, namely the intention behind a certain query. Data about how much a certain issue is searched on Google do not tell us much of *how* such an issue is searched. Operationalizing the relevance of an issue for the public with the sheer count of related users' queries implies ignoring the "sentiment" associated with such relevance. This is the reason why we preferred the more agnostic expression "public attention" to the more connoted one "public opinion".

As explained, *InterestOverTime* retrieved through the Health level of access provides a measure of the relative importance of a search term over the total of Google searches, not a measure of the absolute volume of searches. In principle, and to a large extent, this means that the measure is independent from variables highly correlated with total volume of searches–a specific point time and a country's population, in particular. However, this assumption is not completely valid, as the level of total search activity affects the baseline against which a topic's relative popularity is calculated. This suggests triangulating the findings with data about Google's overall activity over time and across countries.

Another crucial class of limitations relates to the black-boxed nature of Google Trends methodology–a limitation inherent to data collected, organized and made available by a private

[9] Even though they tend to overlap to a large extent nowadays.

corporation with other goals in mind than promoting academic-level research in the public interest. The strategy used by Google to sample users' activity, to compute *InterestOverTime* scores and to identify trending topics is subject to periodical updates, largely unknown to the public. This can introduce more or less significant issues in longitudinal comparison, which requires being cautious with fine-grained analyses of long-term trends.

On a related note, our Topic Analysis largely relied on Google's semantic parsing and knowledge representation strategies, also subject to advancement and update over time, hence casting uncertainty on the interpretation of longitudinal analysis. Furthermore, despite its likely state-of-the-art nature, Google's semantic classification scheme is prone to inconsistencies of sorts–inherent limitations of the organization of natural language expressions into discrete entities. The collected topics vary greatly along the specificity-generality dimension, leaving room for different degrees of semantic consolidation, or even the application of higher-level classification schemes. We opted for a low-key refinement of topics presenting very close semantic content; however, a different approach could more or less significantly affect the frequencies and associations presented in this working version of the paper.

5.2 Expansions

The limitations in terms of operationalization encourage some form of methodological validation of the findings. The country-level timeseries associated with the *InterestOverTime* could be correlated with e.g., EuroBarometer surveys polling the European population on their political priorities. This would allow us to understand if shifts in the prevalence of search activity related to sustainability in a country reflect broader shifts in political priorities. Another interesting possibility would be that of correlating *InterestOverTime* in different countries with the relevance of sustainability in news media, polling databases that offer access to historical annotated data on newspapers. This is of specific methodological interest considering that media attention has also been often used to operationalize broader public opinion dynamics (Downs, 1998; Holt and Barkemeyer, 2012).

As noted, Google Trends data do not discriminate between different intentions and sentiment behind search practices. A strategy to overcome this limitation is to complement the analysis with a focus on literal search queries (see Mellon 2013). Due to our generalistic research goal, in this paper we opted for focusing on *Top/RisingTopic*s, hence semantic entities extracted from literal queries, which circumvent obstacles related to the semantic and language specificity of literal queries. However, through Google Trends it is also possible to retrieve *Top/RisingQueries*, that is to say the literal queries most associated with a search term. This opens up the possibility for more fine-grained explorations of what a certain topic means in a specific timeframe and region.

Relatedly, another meaningful extension of the Trend Analysis would be that of identifying which real-world events are the likely causes of the spikes of interest observed. Introducing Top/RisingQueries is also a way to potentially answer this curiosity. A complementary approach would be that of selecting a number of events topical for the issue of sustainability (e.g., the sign of the Paris Agreement; rise of Friday For Future; Covid outbreak) and evaluate their impact on *InterestOverTime* and on the composition of *Top/RisingTopics*.

We acknowledged how our Topic Analysis is sensitive to how Google translates literal queries into semantic topics–especially to how we decided (not) to aggregate semantically contiguous topics and to deal with the varying generality of the topic. This suggests two lines of expansions: an

assessment of the robustness of the analysis, and a replication with higher-level categories. As for the first, it is probably worth further refining the topic consolidation adopted, and comparing the sensitivity of the results to different versions. An alternative could be that of removing the more general or generic topics (e.g., Sustainable Development, Economy, Project) and let the analysis focus on the most specific/informative ones (e.g., Fashion, Tourism, Transport).[10] As for the second, it would be interesting to apply content analysis to existing topics, in order to classify them into higher-level categories (e.g., Economy and Business; Governance and Politics; Technological Innovation;...). Re-running the analysis presented here with this more abstract classification scheme could allow us to observe higher-level patterns from the more specific observations detailed in this paper.

The analytical directions presented in the findings and those suggested for further research are largely driven by our "generalistic" research goal: exploring how we can leverage Google Trends data to study attention towards sustainability. However, the datasets produced and shared with this research can also be approached with a more specific research interest. For example, one can focus on the evolution of a specific dimension of sustainability, on the role of specific institutional actors, on the effects of specific events. We encourage other researchers to engage in such a "purpose-oriented" exploration of the datasets that we make available.

[10] This is likely to have visible effects on the network structure, potentially letting a more defined modular clustering emerge.

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Repository

Google's Research Agreement does not allow us to publish the data as collected. However, all the notebooks used to collect and analyse the data, together with the processed datasets, are available at: https://github.com/norahahr/SPES_D4.2.

Appendix I

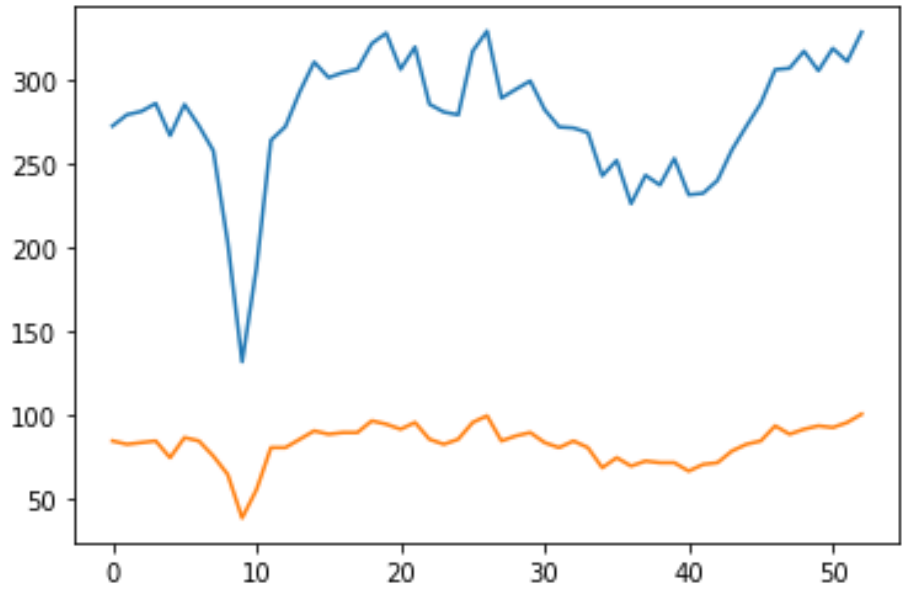

Figure I.1 - The distribution of Health-access InterestOverTime data compared to the distribution of the standard-access data provided by Google's user interface. The comparison shows that health-access data are, to a large extent, the non-normalized version of the interface-access data.

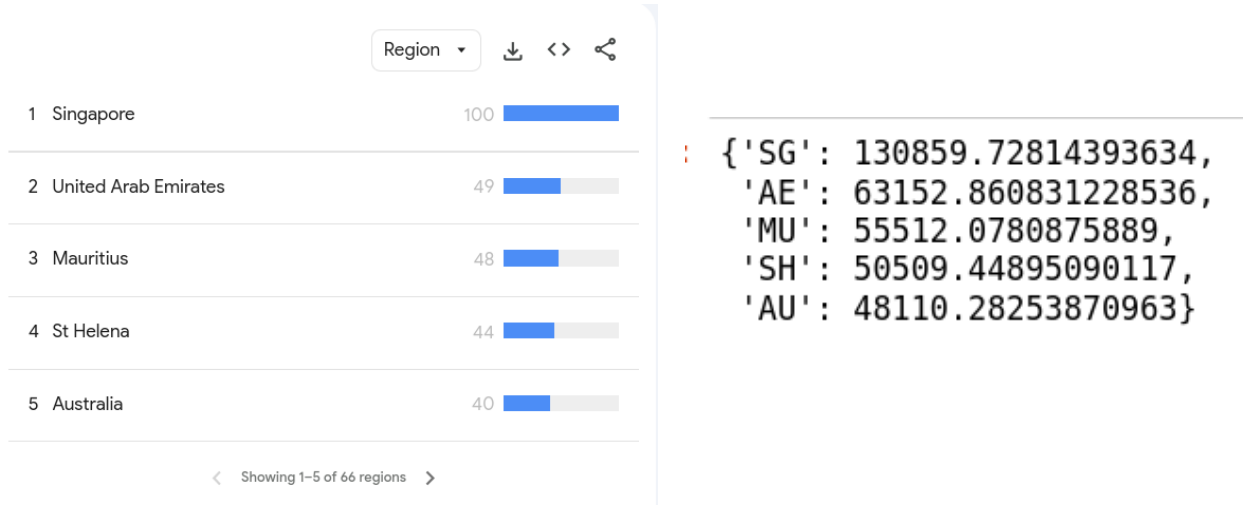

Figure I.2 - Comparison between the ranking of countries obtained through the interface-level InterestByRegion and the ranking of countries based on (cumulative) health-access InterestOverTime in the same timeframe (23/10/2023-23/10/2024), for keyword 'sustainability'. The comparison demonstrates that we can compare health-access InterestOverTime data across countries.

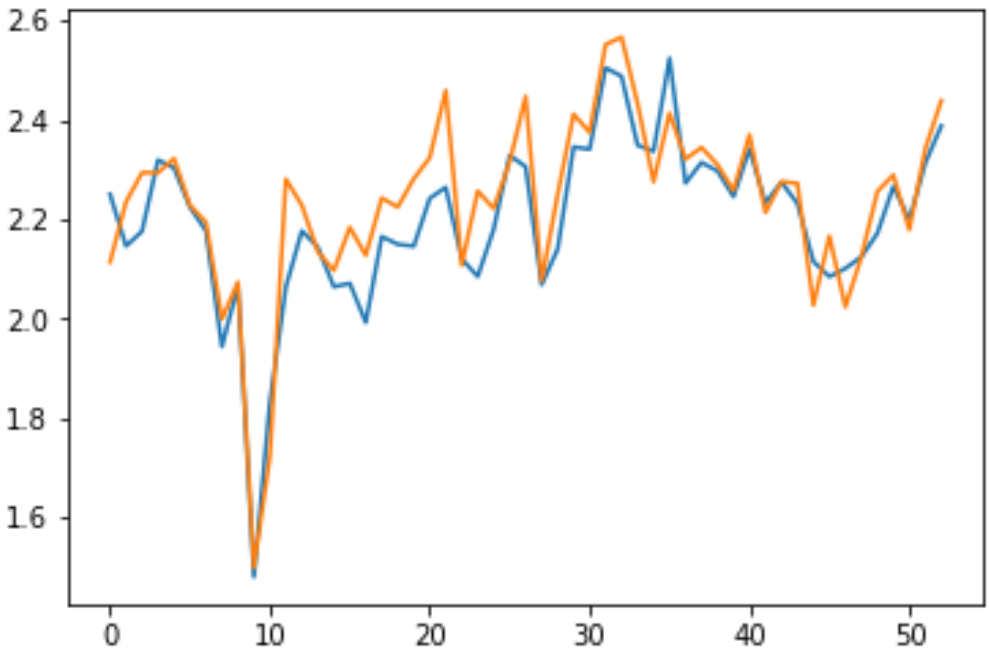

Figure I.3 - The ratio of health-access InterestOverTime across different terms compared to the ratio of standard-access InterestOverTime across different terms, collected from the interface within the same query (22/10/23-23/10/2024, keywords: 'sustainability' and 'productivity'). Despite few differences in trends that we could not explain, the two trends are similar enough for us to reach the same substantial conclusions when comparing the two terms.

Appendix II

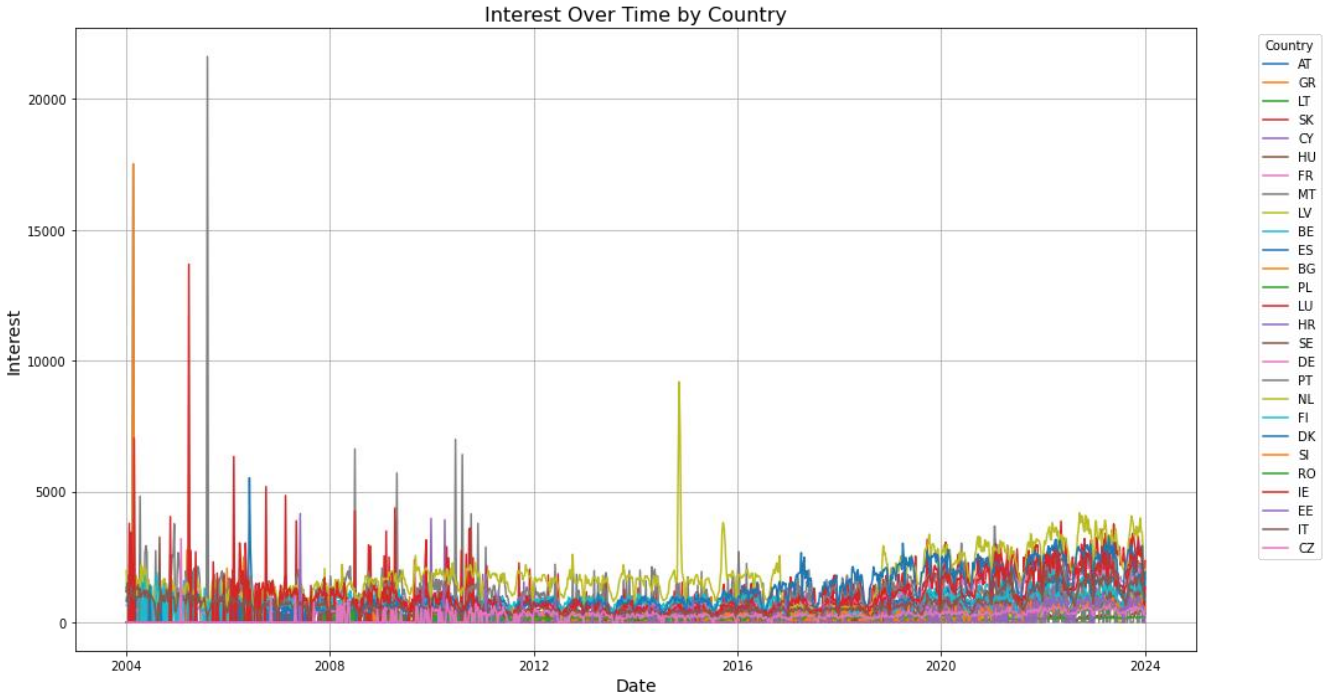

Figure II.1 - Evolution of InterestOverTime per country, 2004-2024.

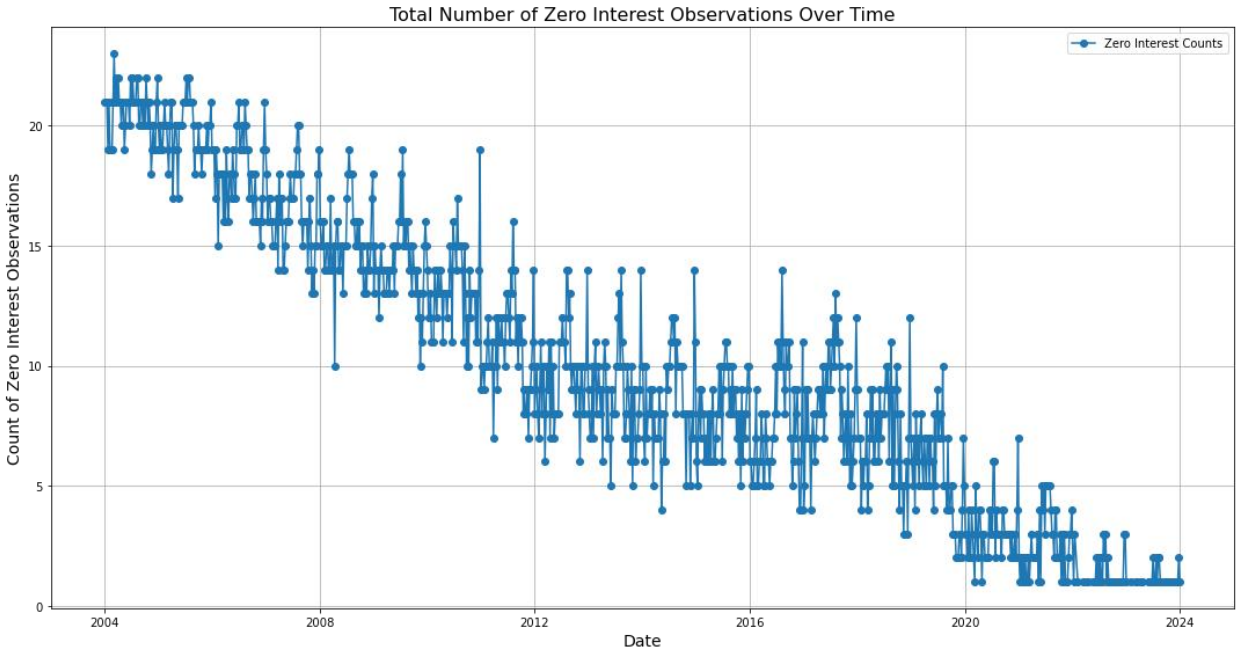

Figure II.2 - Evolution of zero values for InterestOverTime, EU countries, 2004-2024.

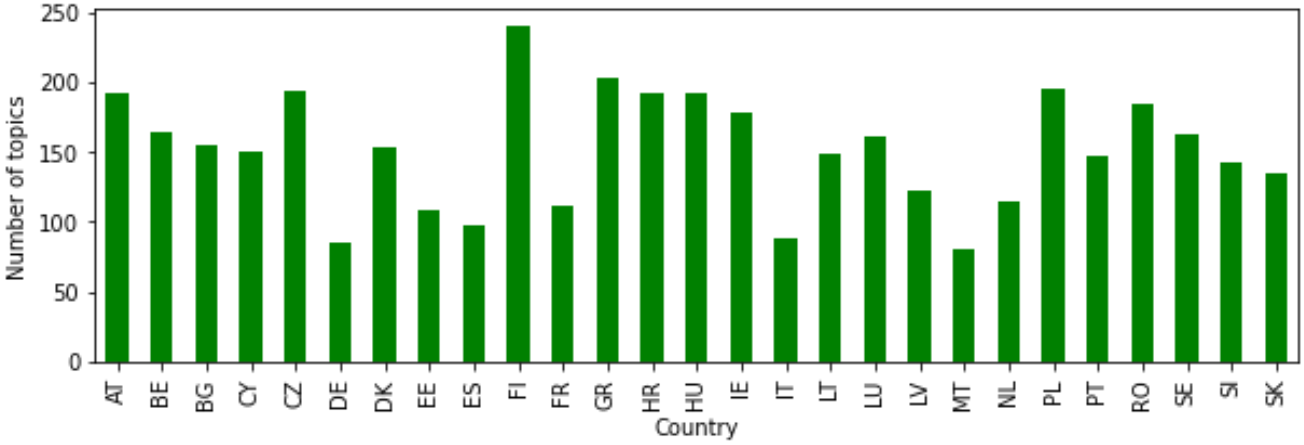

Figure II.3 - Distribution of number of top TopTopics by country, 2004-2024.

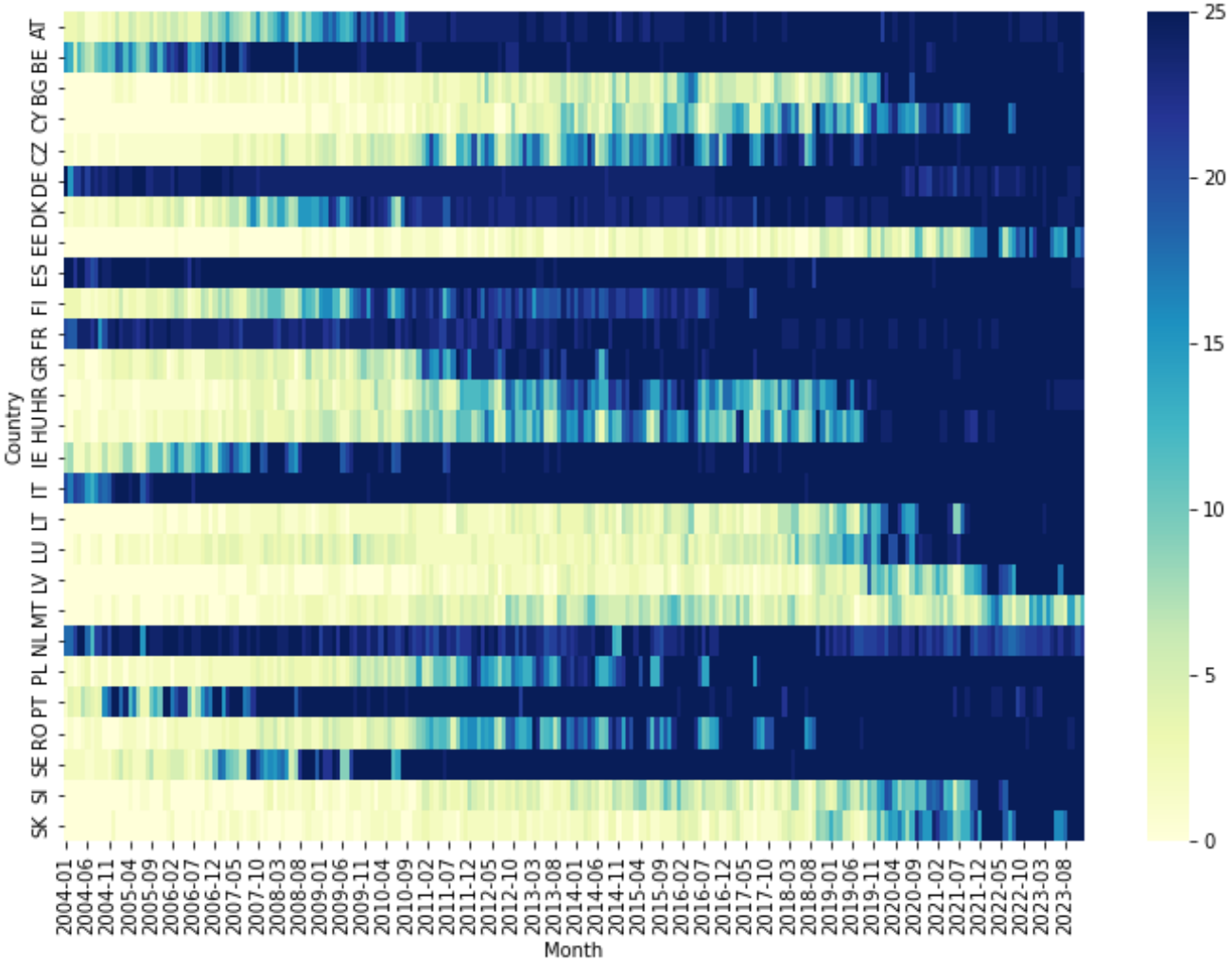

Figure II.4 - Distribution of number of TopTopics by country per month, 2004-2024.

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