#### SHORT COMMUNICATION



# Exploring the digital footprints of migration: insights from google trends and protection seekers' applications to Germany

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# Abstract

This study investigates the potential of using Google Trends data to understand migration dynamics, focusing on people seeking protection in Germany between 2015 and 2019. By analyzing the relationship between changes in migration flows, expressed as percentage changes, and online search interest in Germany from origin countries, the study explores how digital behavior may reflect migration intentions. A weak but statistically significant positive correlation is observed, with regression analyses indicating a stronger relationship when controlling for year- and countryfixed effects. Notably, the coefficient increases markedly when focusing specifically on the top 10 origin countries, highlighting the potential of digital indicators in capturing migration intentions during acute migratory crises. The findings support the hypothesis that spikes in online search interest could signal interest in Germany among people seeking protection prior to migration. Despite limitations such as the reliance on relative search interest and low predictive power in the simple model, the study demonstrates the potential utility of digital data as a supplementary tool in migration research. Integrating such insights with traditional data sources can enhance understanding of the multifaceted drivers behind migration flows.

**Keywords** Migration dynamics · Google trends · Asylum applications · Digital data · Destination selection · Information-seeking behavior · Migration patterns · Early warning signals · Germany · Migration research

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## Introduction

Migration remains a critical issue in global policy discussions, shaped by a complex interplay of factors ranging from conflict and persecution to economic opportunity and social networks. Understanding the motivations behind migration decisions is essential for crafting effective policies that balance humanitarian responsibilities with economic and societal considerations. Among the countries that have seen significant migration flows in recent decades, Germany stands out due to its central role during the 2015 migration crisis. As the country became a primary destination for asylum seekers, questions arose about the drivers behind this influx (Guichard, 2020; Nowak-Lehmann et al., 2021; Torfa et al., 2022) and the extent to which migration decisions are shaped by the search for protection or other factors, such as perceived economic opportunities.

This paper investigates the potential of using digital data to provide insights into migration dynamics. Specifically, it explores the relationship between changes in the number of people seeking protection ("Schutzsuchende"<sup>1</sup>) arriving in Germany and online search interest in the country from their countries of origin. The hypothesis is that spikes in search interest, as measured by Google Trends data, may precede increases in applications by people seeking protection, suggesting a purposeful selection of Germany as a destination. While the findings are speculative and require further analysis to establish definitive conclusions, the study illustrates how online search behavior can be leveraged as a tool to track migration patterns and assess the potential motivations behind them. This approach highlights the growing relevance of digital data in migration research, offering new perspectives that complement traditional data sources.

## Background

The years 2014 to 2019 represent a pivotal period in migration to Germany, characterized by significant changes in asylum seeker flows (Brücker et al., 2019; Jamal & Xie, 2021; Martin, 2016). The migration crisis of 2015 marked a watershed moment, with Germany receiving an unprecedented number of asylum applications driven by factors such as the Syrian civil war, political instability in Afghanistan and Iraq, and

<sup>&</sup>lt;sup>1</sup> Under the term "Schutzsuchende", people seeking protection are defined as foreigners residing in Germany on the basis of international, humanitarian, or political grounds, who are registered in the Central Register for Foreign Nationals (AZR) with the appropriate residence status. This includes three subgroups:

People seeking protection with an open protection status remain in Germany to undergo an asylum procedure, although a decision regarding their protection status has not yet been made.

People seeking protection with recognized protection status possess a temporary or permanent residence permit under the humanitarian provisions of the Residence Act.

<sup>•</sup> People seeking protection with rejected protection status remain in Germany as individuals required to leave after their asylum procedure has been rejected or after losing their humanitarian residence permit (Destatis, 2025a).

economic challenges in parts of Africa and Eastern Europe. Germany's response, which included relatively open asylum policies and an emphasis on humanitarian aid, solidified its reputation as a key destination for those seeking refuge.

However, migration is rarely driven by a single factor. While the need for safety and protection is often the primary motivation, other elements–such as the presence of established migrant networks, perceptions of economic opportunity, and available information about the destination country–also play a role (Morales-Muñoz et al., 2020; Van Hear et al., 2020).

In this context, the internet has become an increasingly important medium for disseminating information about potential migration destinations (Obi et al., 2021; Pesando et al., 2021). Research suggests that online search behavior may serve as a proxy for migration intentions, with spikes in search interest preceding actual migration flows (Böhme et al., 2020; Dekker et al., 2018). Online search data provides unique insights into how individuals seek information, which may reflect their aspirations, concerns, and intentions.

However, scholars caution against overreliance on big data sources like Google Trends (Franzén, 2023). Medeiros and Pires (2021) argue that such data, while valuable, must be contextualized within broader analytical frameworks to account for inherent limitations, such as relative search metrics and confounding external factors. Moreover, online data sources can introduce biases because the heterogeneous representation of migrants varying by continent, socio-economic status, and demographic characteristics such as age and sex systematically affects estimation accuracy (Zagheni et al., 2017).

## Methodology

The study draws on two primary data sources: Google Trends data and statistics from the German Statistical Office, specifically the dataset titled "Schutzsuchende: Deutschland, Stichtag, Geschlecht/Altersjahre/Familienstand, Ländergruppierungen/Staatsangehörigkeit" (Protection Seekers: Germany, Reference Date, Gender/Age (in years)/Marital Status, Country Groupings/Nationality), which records individuals who are recognized as Schutzsuchende in Germany (Destatis, 2025b). Google Trends provides a relative measure of search interest for the topic "Germany" in different countries, offering a proxy for how often people in these countries seek information about Germany. A topic is a collection of search terms that are connected by the same concept or entity, regardless of language, whereas a search term is a precise result that shows only the relative search volume for every term in a query within a specified language. The choice of the topic "Germany" allows covering a broader range of related keywords rather than focusing on one exact search query.

Google Trends is obtained through an automated process that ensures complete user anonymity. Specifically, Google Trends aggregates and normalizes search query data, meaning that individual search records are never disclosed or accessible. The platform provides relative search interest scores scaled from 0 to 100 that reflect the volume of queries related to the chosen topic rather than raw counts. As a result, only fully anonymized and aggregated data is used in the analysis, adhering to strict privacy and data protection standards.

The analysis focuses on all countries with people seeking protection in Germany in 2015–2019.<sup>2</sup> 2015 is chosen as a starting period because it marked a significant turning point in Germany's migration dynamics, driven by a combination of push factors in origin countries and pull factors in Germany. The timeframe extends to 2019 to capture trends before the onset of the COVID-19 pandemic, which drastically altered global migration patterns. By correlating changes in applications by people seeking protection from these countries with search interest in Germany in the preceding year, the study aims to identify patterns that may suggest a link between information-seeking behavior and migration flows.

The analysis considers year-to-year changes in applications by people seeking protection as the dependent variable, while the Google Trends score serves as the independent variable (also see Appendix for details). Pearson correlation coefficient is calculated between the two variables. In addition, a simple linear regression and a regression with country- and year-fixed effects is conducted. While the findings are exploratory, they provide a foundation for understanding how digital data can complement traditional migration statistics.

# Limitations

It is important to acknowledge several limitations of this study, which may affect the interpretation of the findings. First, while a correlation between search interest and applications by people seeking protection may suggest a relationship, it does not establish causation. Factors such as political events, media coverage, and changes in migration policies could simultaneously influence both search behavior and migration flows, making it difficult to isolate the impact of online searches. However, controlling for year- and country-fixed effects in the regression analysis helps mitigate some of these confounding factors by accounting for unobserved heterogeneity and temporal shocks.

<sup>&</sup>lt;sup>2</sup> Countries sorted based on the percentage change of people seeking protection in Germany in 2015: Albania, Syria, Palestinian Territories, Djibouti, Comoros, Kuwait, Namibia, Gambia, Libya, Saudi Arabia, Senegal, Sudan, Honduras, Montenegro, Guinea-Bissau, Venezuela, Mauritania, Afghanistan, South Sudan, Nigeria, Yemen, Central African Republic, Ivory Coast, Turkmenistan, Eritrea, Iraq, North Macedonia, Pakistan, Morocco, Somalia, Benin, Cameroon, Tanzania, Mali, Republic of Moldova, Tunisia, Ukraine, Kosovo, Ethiopia, Tajikistan, Niger, Mongolia, Chad, United States, Burkina Faso, Bahrain, Mexico, Bangladesh, Georgia, India, Egypt, Ghana, Algeria, Equatorial Guinea, Armenia, Sierra Leone, Ecuador, Romania, Indonesia, South Africa, Iran, Liberia, Uganda, Jordan, Cuba, Guinea, Rwanda, Belarus, Mozambique, Azerbaijan, Russian Federation, Serbia, Lebanon, Israel, Philippines, Kenya, Uzbekistan, Republic of the Congo, China, Bosnia and Herzegovina, Argentina, Australia, Bolivia, Botswana, Brazil, Bulgaria, Chile, Dominican Republic, El Salvador, Gabon, Haiti, Jamaica, Canada, Democratic People's Republic of Korea, Republic of Korea, Croatia, Madagascar, Malawi, Malaysia, Nicaragua, Oman, Poland, Slovakia, Taiwan, Thailand, Kazakhstan, Sri Lanka, Kyrgyzstan, Nepal, Vietnam, Togo, Myanmar, Turkey, Angola, Laos, Burundi, Colombia, Cambodia, Democratic Republic of the Congo, Zimbabwe, Peru, Bhutan, Japan, Zambia, Guatemala.

Second, the Google Trends data used in this study measures relative, rather than absolute, search interest. This introduces potential biases, as variations in internet access, literacy rates, and population size across the selected countries could affect the reliability of the data. For example, countries with lower internet penetration may appear to have lower search interest, even if migration intentions are high. Controlling for fixed effects helps adjust for structural differences across countries that could influence the reliability of relative search data.

Third, the study simplifies the motivations behind migration by focusing on search interest as a proxy for economic aspirations. While online searches may reflect perceptions of Germany's economic opportunities, they cannot fully capture the range of factors driving asylum decisions, such as safety concerns, family reunification, or asylum policies. A more comprehensive analysis would require additional data sources, such as surveys or interviews with people seeking protection. The fixed-effects approach partially addresses this limitation by controlling for factors that vary across countries and years, though it cannot fully capture individual-level motivations.

Forth, the timeframe imposes additional constraints. The chosen timeframe does not account for longer-term or shorter-term migration dynamics that may influence the observed patterns. Including year-fixed effects helps address some of these constraints by accounting for temporal shocks and trends within the analyzed period, though longer or more granular datasets would enhance the robustness of the findings.

Finally, the analysis assumes that search interest in Germany from the origin country directly precedes migration applications. However, migration decisions are often multi-stage processes, where individuals may leave their country of origin first and only later, while in transit countries, seek information about potential destinations. This study's design, which correlates origin-country searches with subsequent applications, does not account for such intermediate stages, potentially overlooking the dynamic and non-linear nature of migration decision-making.

# **Results and discussion**

The findings of this study complement existing research by reinforcing the argument that online search behavior can act as an indicator of migration intentions (Böhme et al., 2020; Dekker et al., 2018) and by highlighting the importance of migrant heterogeneity (Zagheni et al., 2017). Specifically, the observed correlations between Google Trends data and shifts in applications by people seeking protection in Germany illustrate how digital footprints may signal emerging migratory pressures before they materialize in official statistics. At the same time, the varied strength of these relationships, especially when comparing the top 10 origin countries with a broader sample, underscores the need to account for complex, context-specific drivers that cannot be fully captured by a single measure of online search interest. The discussion that follows situates these findings within the scholarly debate on integrating big data sources into more robust migration forecasting frameworks, while

also considering the practical implications and limitations of using digital indicators in this domain.

#### **Correlation analysis**

The analysis reveals a weak but statistically significant positive correlation (r=0.082, p=0.041) between Google Trends search interest for Germany and changes in applications by people seeking protection in Germany from selected countries during the 2015–2019 period. Although this correlation indicates that search interest alone has limited standalone predictive power, it is consistent with earlier studies suggesting that digital traces such as search queries can partially reflect migratory intentions and information-seeking behaviors prior to migration decisions (Böhme et al., 2020; Dekker et al., 2018).

Critically, these findings reinforce the cautionary arguments made by Medeiros and Pires (2021) and Raubenheimer (2023) against overestimating the predictive power of big data sources like Google Trends when used in isolation. Nevertheless, a more detailed subgroup analysis reveals that when the focus is narrowed to countries experiencing the largest relative increases in applications from people seeking protection in Germany, the correlation strengthens markedly. For the top 10 countries as of 2015, the correlation rises substantially to 0.317 (p=0.025), lending support to Connor's (2017) research which emphasizes that digital indicators become increasingly meaningful during acute migratory crises.

Furthermore, expanding the analysis to include larger groups of countries demonstrates a consistent pattern of diminishing correlation strength. Specifically, the correlation is 0.199 (p=0.047) for the top 20 countries, 0.165 (p=0.043) for the top 30 countries, and 0.138 (p=0.052) for the top 40 countries. This progressive weakening aligns with the argument of migration heterogeneity posed by Zagheni et al. (2017), highlighting that including a broader array of countries with potentially diverse migratory motives and dynamics (for example, OECD countries such as the United States that may experience different migratory pressures) can dilute the observable digital signals.

#### **Regression analysis**

The regression analyses deepen our understanding of the relationship between Google Trends search data and migration flows of people seeking protection in Germany. Initially, a simple linear regression reveals a modest yet statistically significant predictive relationship ( $\beta$ =0.135, p=0.041; see Table 1). This coefficient indicates that for every 1-unit increase in the Google Trends score, migration flows increase by approximately 0.135%. Despite its statistical significance confirmed by the F-test (p=0.041), the low explanatory power ( $R^2$ =0.007) underscores the limited predictive capability of standalone digital indicators, aligning with the broader academic view that digital data alone are insufficient to predict migration accurately. This finding resonates with studies advocating integrated modeling approaches; for instance, Mihai and Novo-Corti (2022) propose models that combine economic,

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$\Delta$ People seeking protection	Coef	St.Err	t-value	p value	[95% Conf	Interval]	Sig				
Google Trends Score	0.135	0.066	2.05	0.041	0.006	0.264	**				
Constant	20.331	2.021	10.06	0	16.361	24.3	***				
Mean dependent var		20.081	SD dependent var			50.369					
R-squared		0.007	Number of obs			620					
F-test		4.204	Prob > F			0.041					
Akaike crit. (AIC)		6618.318	Bayesian crit. (BIC)			6627.177					

 Table 1
 Simple linear regression

\*\*\*\* *p* < 0.01, \*\* *p* < 0.05, \* *p* < 0.1

social, cultural, and digital dimensions. Qi and Bircan (2023) similarly demonstrate that the predictive efficacy of Google Trends varies significantly depending on the complexity of the analytical model. Additionally, Hsiao et al. (2020) illustrate improved migration estimates through the combination of digital and survey data.

The inclusion of year- and country-fixed effects substantially enhances the explanatory power of the model, increasing the  $R^2$  from 0.007 to 0.334 and strengthening the Google Trends coefficient to 0.243 (p=0.005; see Table 2). After accounting for these fixed effects, each 1-unit increase in Google Trends search interest corresponds to a 0.243% rise in migration flows to Germany, with high statistical significance at the 1% level. This improvement is supported by the F-test (p=0.000), underscoring the robustness of the enhanced model.

These enhanced results align closely with Spyratos et al. (2019), who emphasize the critical importance of controlling for temporal and spatial dynamics when analyzing migration patterns through digital data. The marked improvement in model fit further validates the complementary role of big data sources alongside traditional migration indicators (Tjaden, 2021).

Moreover, these findings empirically support hypotheses by Zagheni and Weber (2012) and Dubois et al. (2018), proposing that online search behaviors reflect preliminary information-seeking activities predictive of migration intentions. Consistent with these perspectives, the results suggest that spikes in online search interest can indeed serve as early signals of migration movements. However, the analysis also reinforces critical perspectives urging caution in interpreting digital data due to inherent limitations, such as reliance on relative rather than absolute measures of search intensity and incomplete capturing of migration intentions.

# Conclusion

This study highlights the value of Google Trends data in exploring migration dynamics, specifically applications by people seeking protection in Germany. The analysis reveals a statistically significant but weak positive relationship between online search interest and changes in migration flows. When year- and country-fixed effects are included, the relationship becomes stronger, suggesting that digital behavior

$\Delta$ People seeking protection	Coef	St.Err	t-value	p value	[95% Conf	Interval]	Sig
Google trends score	0.243	0.086	2.83	0.005	0.074	0.412	***
Constant	46.833	21.025	2.23	0.026	5.523	88.143	**
Year-fixed effects	Yes						
Country-fixed effects	Yes						
Mean dependent var		20.081	SD dependent var			50.369	
R-squared		0.334	Number of obs			620	
F-test		1.920	Prob > F			0.000	
Akaike crit. (AIC)		6624.965	Bayesian crit. (BIC)			7196.399	

Table 2 Linear regression with country- and year-fixed effects

\*\*\*\* *p* < 0.01, \*\*\* *p* < 0.05, \* *p* < 0.1

offers meaningful insights when contextualized within broader frameworks. Importantly, the observed relationship becomes substantially stronger when narrowing the focus to the top 10 countries, underscoring the heightened relevance of digital signals during significant migratory episodes.

The findings support the hypothesis that spikes in online search interest may indicate pre-migration interest in Germany among people seeking protection, aligning with the idea that information-seeking processes precede physical migration. However, the study underscores the complexity of migration drivers and the need for integration with traditional data sources to fully capture these dynamics.

While digital data can serve as an early warning system for shifts in migration patterns, its limitations, including reliance on relative interest and low predictive power in simpler models, emphasize the importance of a comprehensive approach to understanding migration behavior. This study contributes to the growing field of digital migration research, illustrating how new data sources can complement existing methods to provide a more nuanced view of migration trends.

## Appendix

## Methodology and analytical framework

Let  $G_t(c)$  represent the Google Trends score for a given country c in year t, where t is the year of measurement. This serves as the independent variable.

Let  $A_t(c)$  represent the number of applications by people seeking protection from country c to Germany in year t. The year-to-year change in applications is:

 $\Delta A_t(c) = \frac{A_t(c) - A_{t-1}(c)}{A_{t-1}(c)} * 100 \text{ where } \Delta A_t(c) \text{ is the percentage change in applica$ tions for country c between years t and t - 1.

The study considers the Google Trends score from the preceding year as a predictor of migration. Thus, for a given year t, the lagged Google Trends score is  $G_{t-1}(c)$  The Pearson correlation coefficient r is calculated between  $\Delta A_t(c)$  (dependent variable) and  $G_{t-1}(c)$  (independent variable) across all countries c over the time-frame T (2015–2019).

The exploratory relationship between search interest and migration flows can be expressed as:

 $\Delta A_t(c) \propto G_{t-1}(c)$ 

This relationship implies that changes in applications are potentially influenced by lagged Google Trends scores, although this is not necessarily causal.

For the simple linear regression model, the relationship between the lagged Google Trends score  $G_{t-1}(c)$  and the percentage change in applications  $\Delta A_t(c)$  is expressed as:

 $\Delta A_t(c) = \beta_0 + \beta_1 G_{t-1}(c) + \varepsilon$  where:

- $\beta_0$  is the intercept,
- $\beta_1$  is the coefficient representing the relationship between  $G_{t-1}(c)$  and  $\Delta A_t(c)$ ,
- $\varepsilon$  is the error term.

The fixed-effects model refines the analysis by controlling for unobserved heterogeneity that varies across countries and years. The percentage change in applications is modeled as:

 $\Delta A_t(c) = \beta_0 + \beta_1 G_{t-1}(c) + \gamma_c + \mu_t + \varepsilon \text{ where:}$ 

- $\gamma_c$  captures country-specific fixed effects, accounting for time-invariant factors unique to each country (e.g., geographical location, baseline migration dynamics),
- $\mu_t$  represents year-specific fixed effects, accounting for global or region-wide temporal shocks (e.g., migration policies, political events),
- $\beta_0, \beta_1$ , and  $\varepsilon$  retain their interpretations.

By incorporating  $\gamma_c$  and  $\mu_t$ , the model controls for confounding influences that could bias the relationship between  $G_{t-1}(c)$  and  $\Delta A_t(c)$ , offering a more robust estimation of the relationship. This approach allows the model to better isolate the influence of lagged Google Trends scores on percentage changes in applications by people seeking protection while acknowledging the broader structural factors affecting migration dynamics.

Author contributions D.E. conceived and designed the study, collected and analyzed the data, and wrote the manuscript. The author reviewed and approved the final manuscript.

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Data availability Data is publicly available.

#### Declarations

Competing interests The authors declare no competing interests.

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