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Where have Ukrainian refugees gone? Identifying potential settlement areas across European regions integrating digital and traditional geographic data

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Abstract

The escalation of conflict in Ukraine has triggered the largest refugee crisis in Europe since WWII. As of early April 2024, over 5.9 million people have fled Ukraine. Large-scale efforts have been made to identify the major receiving countries. However, less is known about the subnational areas within host countries where refugees have migrated. Identifying these areas is key for the appropriate allocation of humanitarian aid. By combining digital Facebook API data and traditional data from Eurostat, this paper aims to identify and characterise potential settlement areas of Ukrainians across the main destination countries in Europe. We identify high concentrations of Ukrainians in urban areas with a preexisting diaspora and tight labour market conditions across southern, northern-west and central Poland and the city of Prague in the Czech Republic. We also find potential settlements in key urban agglomerations with a moderate diaspora and high levels of unemployment in Spain. Only in Romania, refugees seem to have settled in rural areas which show a moderate diaspora but low levels of unemployment. Potential settlement areas in Germany, Italy and the United Kingdom are spread across the country. Surprisingly, we do not identify potential settlement areas in bordering regions with Ukraine within neighbouring countries, suggesting that refugees may have used them as transit points. Our findings point out that different packages of humanitarian assistance may be needed according to the number of refugees and the characteristics of settlement areas.

KEYWORDS

Big data, Europe, Facebook data, settlement, Ukrainian refugees

1 | INTRODUCTION

The escalation of armed conflict in Ukraine on 24 February 2022 has triggered the largest refugee crisis in Europe since World War II (Murray, 2022). Fear resulting from large numbers of civilian casualties and destruction of civilian infrastructure has forced people to flee their homes seeking safety, protection and assistance [United Nations High Commissioner for Refugees (UNHCR), 2023a]. Over 6.5 million of Ukrainians were internally displaced from their region by 10 May 2022 (Leasure et al., 2023), and close to 5.9 million of refugees were recorded across Europe by early April 2024, the majority in the neighbouring countries of Poland, Czech Republic, Romania and

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Slovakia; and non-neighbouring countries of Germany, Italy, Spain, the United Kingdom and Turkey (UNHCR, 2023a). Some of these countries were potential destinations of immigrants from Ukraine before the Russian invasion. Thus, a Ukrainian diaspora have already existed and a large share of refugees may have moved to countries where they had an established social network (Best & Menkhoff, 2022; Minora, Belmonte, et al., 2022; Minora, Bosco, et al., 2022).

Displaced populations are in need of protection and humanitarian assistance to ensure their safety, overall health and well-being, especially in settlement areas where they have not supporting networks. They require food, shelter, financial aid and healthcare to meet basic needs, and access to education and employment to generate an income and achieve self-sustainability (Panchenko, 2022; UNHCR, 2022a; Zeng, 2022). In this context, areas with low levels of unemployment are more likely to integrate refugees in their labour market (Bahcekapili & Cetin, 2015; Panchenko, 2022). Population displacements entail impacts on receiving societies involving an increased demand for public services, including schools and healthcare facilities. Areas with high population densities and concentration of infrastructure may have the capacity to provide these services, while rural areas may lack the capacity to do so. High resolution geographical data in real-time are critical to identify and assess population displacement in host settlement areas where demand for employment and services is expected to increase and thus ensure appropriate provision of humanitarian aid.

Traditional data sources are constrained to render information at such high temporal and geographical resolution. Traditional data systems are not regularly updated, costly and are characterised by slow data collection and release (Green et al., 2021). Yet, valuable data collection efforts have been made by the United Nations to monitor the overall scale of the Ukrainian refugee crisis. Thus, we now have an understanding of the volume and distribution of Ukrainian refugees across countries and estimates of a steady flow of border crossings from Ukraine into neighbouring countries (UNHCR, 2023a). However, less is known about the subnational patterns of population displacement from Ukraine in destination countries and the type of settlement areas where refugees are settling once they crossed the border into neighbouring countries. Digital footprint data have emerged as a key source of information, offering an opportunity to capture human population movements at highly geographical and temporal scales in multiple countries (Rowe, 2023). Integrating of traditional and innovative data sources provides a effective way to estimate population movements (Garrido-Graells et al., 2023). Drawing on data from Facebook and Eurostat, this paper aims to identify and characterise the potential settlement areas of Ukrainian refugees in the main host countries at NUTS 3 levels, and explore the role of Ukrainian diasporas in shaping the settlement patterns of Ukrainian refugees. Specifically, we seek to address the following questions:

1. Which are the main potential settlement areas of Ukrainian refugees within the receiving countries?
2. What is the role of existing diasporas in shaping the settlement patterns of refugees within receiving countries?
3. Which type of regions are absorbing Ukrainians refugees? Are they settling in urban or rural areas?
4. Are refugees settling in areas with employment opportunities?

The next section offers a brief overview of the current knowledge of population displacements within and outside Ukraine. Next, we describe the methods and data used for our analysis before presenting the results divided into three subsections. First, we present a preliminary analysis of settlement patterns and the Ukrainian diaspora at the national level using data from UNHCR and Eurostat. Second, we identify settlement areas of Ukrainians within the main host countries at the NUTS 3 level using the number of Facebook Daily Active Users (DAU) who use Ukrainian as the main language and explore the relationship between a high concentration of Ukrainian-speaker users and the existence of a previous diaspora using the Facebook Social Connectedness Index (SCI). Third, we use multilevel negative binomial regression modelling to analyse the association between the number of Ukrainian DUA and the SCI controlling for key contextual factors, including population density and unemployment, that may influence their settlement choices. Finally, we summarise our key findings and discuss potential implications.

2 | BACKGROUND

The Ukraine War has triggered a number of internal displacements and a mass exodus to other countries (Ueffing et al., 2023; UNHCR, 2023a). Previous studies estimated that 6.5 million people were internally displaced away from their region as of 10 May 2022 (Leasure et al., 2023; Rowe et al., 2022). They reveal large population losses in eastern, southern and northern Ukrainian regions with a high concentration of armed conflicts, particularly in Khersonska (59%), Kharkivska (55%), Kyiv (45%) and their neighbouring regions, and gains in western areas bordering Poland, Slovakia, Hungary, Romania and Moldova, especially in Chernivetska (18%), Livivska (16%) and Vinnytska (11%). These increases are likely to reflect a large amount of transitory population movements and the function of these regions as access points to neighbouring countries (Rowe et al., 2022). These studies found reductions in female and young populations across the country and increases in male populations in central and western regions. These contrasting patterns in gender and age reflect the existing martial law for male Ukrainian citizens aged 18–60 enacted on 24 February 2022 and the fact that females and children comprise the main groups of Ukrainians displaced internally and refugees.

As of early April 2024, UNHCR recorded 5.9 million refugees displaced to other countries (UNHCR, 2023a). Early reports estimated that around 90% of refugees were women and children (Ramsay, 2022). Over 5.4 million have registered for temporary protection or similar national protection schemes (UNHCR, 2023a). In addition, about 29.1 million movements out of Ukraine have been recorded, and over 25 million into the country (UNHCR, 2023a). Reportedly, the number of borders crossing out of Ukraine has

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declined after a peak in March 2022, while movements into Ukraine increased as the conflict shifted its focus towards eastern and southern regions away from Kyiv (UNHCR, 2022b). Border crossing movements have been noted to be pendular (UNHCR, 2022b). They do not necessarily represent a long-term return to Ukraine, as people move in and out of the country for humanitarian and military assistance as well as fleeing the conflict.

The majority of refugees exit Ukraine by moving to neighbouring countries on the western border. Poland has been the main receiver of refugees from Ukraine. As of early-April, 2024, Poland recorded close to 1.6 million Ukrainian refugees (UNHCR, 2023a). Large numbers of refugees have also been recorded in other neighbouring countries: Czech Republic (590+ thousand), Slovakia (139+ thousand), Moldova (113+ thousand), Romania (159+ thousand) and Hungary (41+ thousand) (UNHCR, 2023a). Some refugees use these countries as transit points since special migration schemes have been developed to facilitate the entry of Ukrainian refugees into other countries across Europe (EU, 2022). However, observers have anticipated that a large share of refugees are likely to stay in Poland and other Eastern European countries because of tight labour market conditions, relatively affordable cities and a preexisting diaspora (Hinshaw & Lovett, 2022). Other non-neighbouring destinations also emerged as important receivers of Ukrainian refugees, such as Germany (more than 1.1 million), the United Kingdom (255+ thousand), Spain (200+ thousand), Italy (191+ thousand) and Turkey (42+ thousand).

Migrant diasporas have long been established as a key factor influencing migrant choices to settle in key locations (Beine et al., 2011; Migali et al., 2018). Migration networks facilitate the arrival and integration of immigrants (Curran & Rivero-Fuentes, 2003; Haug, 2008). In the context of the Ukrainian refugee crisis, studies have identified European regions with large Ukranian diasporas (Best & Menkhoff, 2022; Minora, Belmonte, et al., 2022; Minora, Bosco, et al., 2022). Ukrainian refugees are, therefore, likely to have moved to these regions. Identifying whether a diaspora exists in settlement areas is essential for managing humanitarian assistance. The arrival of refugees in areas where there is no diaspora would create a greater need for humanitarian support among displaced populations.

Additionally, anecdotal reports have suggested large concentrations of Ukrainian refugees in major urban centres, such as Berlin and Warsaw. Yet, rural areas across Europe have also been identified as receiving centres of Ukrainian refugees (Allaby, 2022; Galloway, 2022; Zavialova, 2022). These reports thus differ from the prevalent pattern of migrants settling primarily in urban areas (Duncan & Ioana, 2017). Evidence analysing the settlement patterns of Syrian refugees in Europe indicates that most refugees moved to urban agglomerations (Kılıçaslan, 2016). Sparsely and less populated areas tend to be less attractive for international migrants (Chiswick & Miller, 2004; González-Leonardo, 2020, 2021). To date, there is limited evidence on the extent to which Ukrainian refugees are settling in rural areas within host communities. Our work seeks to provide an understanding of the settlement patterns across the rural–urban hierarchy in destination countries. Such understanding is key to ensuring the appropriate allocation and resources where they are needed.

A key overlapping issue is the availability of employment opportunities in local areas of settlement. Local availability of employment opportunities is important for refugees to generate an income and achieve self-sustainability (UNHCR, 2022a; Backman et al., 2021). Previous studies have documented the challenges experienced by Syrian refugees in finding a job in areas with high unemployment rates (Bahcekapili & Cetin, 2015). In contrast, low levels of unemployment have been associated with better employment opportunities for Syrian refugees (Panchenko, 2022; Vogiazides & Mondani, 2020). Taken together, the cumulative evidence suggests that low levels of unemployment tend to facilitate labour market integration among displaced populations. In this study, we analyse the extent to which Ukrainian refugees are settled in areas of low or high unemployment. Such information is critical to provide refugees with information of local employment opportunities and enhance humanitarian assistance in areas of high unemployment where refugees may experience difficulties finding a job.

Overall, existing work has provided an understanding of the scale and receiving countries of Ukrainian refugees. Less is known about the subnational areas of settlement where Ukrainian refugees may have been migrating to. We seek to identify potential settlement areas of Ukrainian refugees within destination countries and characterise these areas in terms of the existence of a previous diaspora, population density and unemployment rates.

3 | DATA AND METHODS

Our analysis comprises three stages, including different layers of information (Figure 1). First, we analysed the number of Ukrainian refugees using UNHCR data and the Ukrainian diaspora from Eurostat counts at the national level to offer a cross-country representation. Second, we identified potential settlement areas within the main destination countries in Europe using the number of Facebook DAU who use Ukrainian as the main language at the NUTS 3 level and analysed the relationship between settlement patterns and the Facebook SCI with Ukraine before the Russian invasion to identify if Ukrainians have moved where they have a preexisting diaspora. Third, we assessed the ecological associations between the number of Ukrainian DUA and the SCI controlling for key contextual factors, including population density and unemployment, that may contribute to shape their settlement choices using a multilevel Negative Binomial Regression Model (NBRM).

3.1 | Stage 1. Analysis at national level

First, we give an overview on the main receiving countries of Ukrainian refugees and the role of a preexisting diaspora. We used a scatter plot to explore the relationship between the size of the Ukrainian refugee influx and the population of Ukrainian citizens residing in receiving countries across Europe. To this end, we used refugee data from the UNHCR Ukraine Refugee Data Portal dating to mid-April 2023 and identify refugees as 'refugees from Ukraine recorded in the country'

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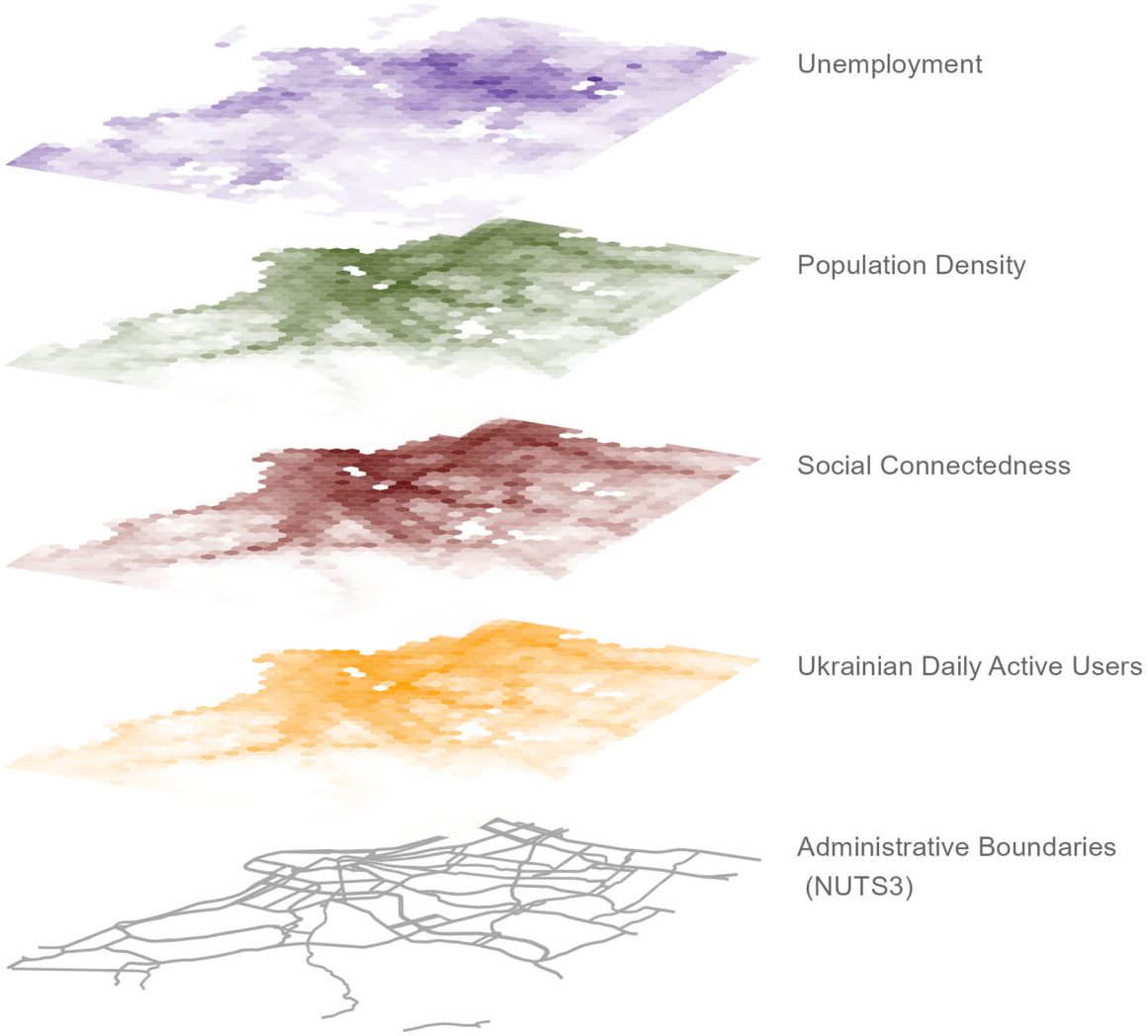

FIGURE 1 Integration of subnational level data.

(UNHCR, 2023b). Data on population counts of Ukrainian citizens living in European countries in 2021 were obtained from Eurostat (data product: migr_pop1ctz).

3.2 | Stage 2. Identifying potential settlement areas within host countries and assessing the relationship with a preexisting Ukrainian diaspora

Second, we sought to identify potential settlement areas within the main receiving countries at the NUTS 3 level. For that purpose, we focused on the neighbouring countries of Ukraine (Poland, Czech Republic, Slovakia, Romania and Hungary) and non-neighbouring countries which have registered more than 150,000 refugees at some point during the armed conflict (Germany, Italy, Spain, the United Kingdom and Turkey). We excluded Moldova as a bordering country because the national territory is not divided into NUTS 3 regions, and no data were available on Eurostat for Moldova.

To identify potential settlement areas of Ukrainians in host countries, we used the number of Facebook users who use Ukrainian as their primary language during social interactions on Facebook. To mitigate fluctuations in the frequency of Facebook use across areas, we used data for 2 weeks from 28 January and 12 February2023 and computed the median number of Facebook DAU. We selected a period between the end of January and early February to avoid public holidays or seasonable events that could affect our results (e.g., Christmas, student mobility, summer holidays). We used the median DAU as this measure was suggested by Gil-Clavel et al. (2021) to deal with small Facebook populations. Facebook DAU data were extracted using the Facebook Marketing API (Meta, 2022a). The Facebook Marketing API is a free tool that allows access to the Facebook Adverts Manager programmatically. It gives advertisers the approximate number of Facebook users that match specific characteristics (Zagheni et al., 2017).

Intuitively, we sought to define potential settlement areas for Ukrainian refugees by identifying NUTS 3 regions with comparatively a large number of Facebook DAU who used Ukrainian as the main language. The values depend on how many users connected to Facebook during the previous 24 hours. The numbers of Facebook DAU can be zero when no users logged in during the last 24 hours. For privacy concerns, Facebook sets the number of users to 100 if 100 or less than

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100 users logged in. In any other case, values are greater than 100 and correspond to the number of users who logged in. To visualise our results, we mapped the number of DAU at the NUTS 3.

We then explored the relationship between potential settlement patterns of refugees and a preexisting Ukrainian diaspora. To this end, we used the Facebook SCI as a proxy for Ukrainian diasporas (Bailey et al., 2018). We used a scatter plot and a bivariate map to establish the association between a high concentration of Facebook DAU and a preexisting high social connectivity with Ukraine. The SCI comes from users who shared their location during August 2020, and the data were accessed via Facebook Data for Good Initiative Portal. The SCI measures the degree of connectivity between places by estimating the number of shared friends between Facebook users in two different locations (Meta, 2022b). We used it to measure the intensity of connectivity between Ukraine and NUTS 3 regions across Europe before the Russian invasion. To bolster the credibility of using the SCI as a proxy for the Ukrainian diaspora, we showed a scatter plot between the SCI and data on the prewar Ukrainian citizens in Figure 1 of the Supporting Information. These data were collected from national statistical offices of Poland, Czech Republic, Slovakia, Hungary, Germany, Italy and Spain at the NUTS 3 levels, except for Poland where data were available at the NUTS 2 level.

3.3 | Stage 3. Determining the associations between the number of Ukrainian DUA and key contextual factors

We aim to characterise the settlement areas according to the SCI, population density and employment opportunities. We first analysed the association between the numbers of Facebook DAU with population density and existing levels of unemployment in host countries at the NUTS 3 level. As in Stage 2, we measured these relationships using scatter plots and bivariate maps. We used population density data (data product demo_r_d3dens) and unemployment rates (data product lfst_r_lfu3rt) from Eurostat in 2021, except for the United Kingdom. For the UK, we used 2021 Census data since information is no longer available in Eurostat.

Next, we estimated an multilevel NBRM to understand the relationship between the settlement patterns of Ukrainian DAU with the SCI, population density and unemployment. We considered population density as quintiles (very low, low, medium, high, very high) to understand the observed non-linearities in the relationship between DAU and population density across countries. Following Rowe et al. (2021), we used an multilevel NBRM to account for the right-skewed and over-dispersed distribution of the count of Ukrainian DAUs. We fitted a random intercept and random slope NBRM. We allowed parameters to vary across countries to account for cross-national variability in the local levels of Ukrainian DUA and in the relationship between DUA and the SCI. We focused on the SCI as we argue that this index is a key predictor of where Ukrainian refugees have decided to settle based on the body of cumulative evidence indicating that immigrants tend to settle in areas with large and dense diasporas. Formally, the estimated model is as follows:

$$DAU_{ic} = f(a_{0c} + \beta_1 \text{unemp}_{ic} + \beta_{2c} SCI_{ic} + \beta_3 \text{popdensity}_{ic}) + \varepsilon_{ic}$$

$$a_{0c} = a_0 + u_{0c}$$

$$\beta_{2c} = \beta_2 + u_{2c}$$

DAU captures the number of Ukrainian DAU in an administrative area *i* within the country *c*; a_{0c} is a random intercept that varies by country; *unemp*, *SCI* and *popdensity* are as defined earlier the local unemployment rate, SCI and population density quantile, respectively; β_1 – $\beta_3$capture the average relationship between each of these predictors and the count of Ukrainian DAU. a_{0c} encodes the random intercept capturing the varying level of Ukrainian DAU across countries; and, β_{2c} indicates a random slope capturing the varying relationship between the count of Ukrainian DAU and the SCI across countries; ε_{ic}, u_{0c}, u_{2c} are error terms.

4 | RESULTS

4.1 | Analysis at the national level

As indicated, the escalation of the conflict in Ukraine has triggered a refugee exodus of 5.9 million people, with Poland, Germany and the Czech Republic collectively absorbing almost 38% of all refugees. To establish some grounding, Figure 2 displays the country-level association between the size of the current Ukrainian refugee influx and the size of the Ukrainian citizen population for European countries. It shows a positive association reflecting that countries with more extensive communities of Ukrainian citizens in 2021 have been attracting the largest influxes of refugees, such as Poland, Germany Czech Republic, Italy and, to a lesser extent, Spain. By contrast, countries with a smaller Ukrainian diaspora have registered a more moderate influx, including Greece and Croatia. However, some countries with a relatively small Ukrainian diaspora, such as Turkey, Slovakia and Romania, have recorded higher than expected numbers of refugees. Similarly, Portugal records a smaller than expected number of Ukrainian refugees despite having the sixth-largest diaspora of Ukrainian migrants in Europe.

4.2 | Identifying potential settlement areas within host countries and assessing its relationship with a preexisting Ukrainian diaspora

Next, we use the mean of Facebook DAU who used Ukrainian as the primary language between 28 January and 12 February 2023 to identify the potential settlement areas of Ukrainian refugees at the subnational level in the neighbouring countries (Poland, Slovakia, Czech Republic, Hungary and Romania) and the main non-neighbouring receiving countries, including Germany, Italy, Spain, the United Kingdom and Turkey (Figure 3). In Poland, as the main destination country of Ukrainian refugees, Warsaw (Poland) emerges

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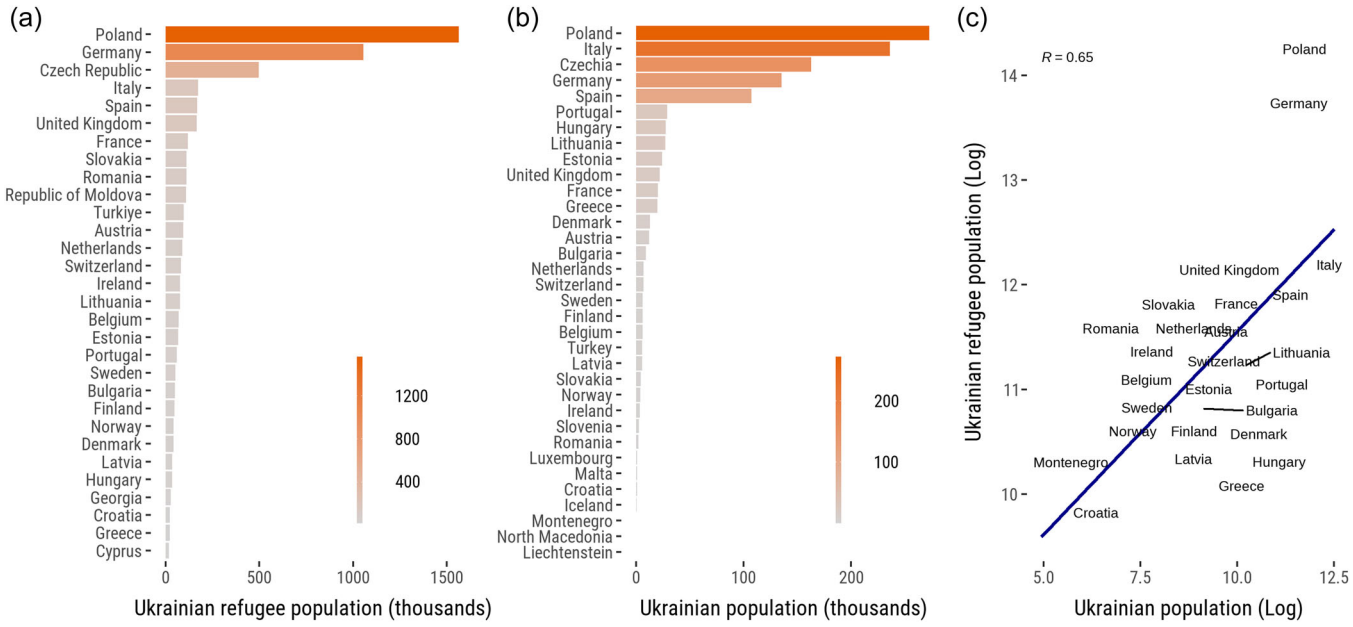

FIGURE 2 Ukrainian refugee population count by destination country, mid-April 2022 (a); population with Ukrainian citizenship count by country, 2021 (b); and Ukrainian refugee population count versus population with Ukrainian citizenship (c).

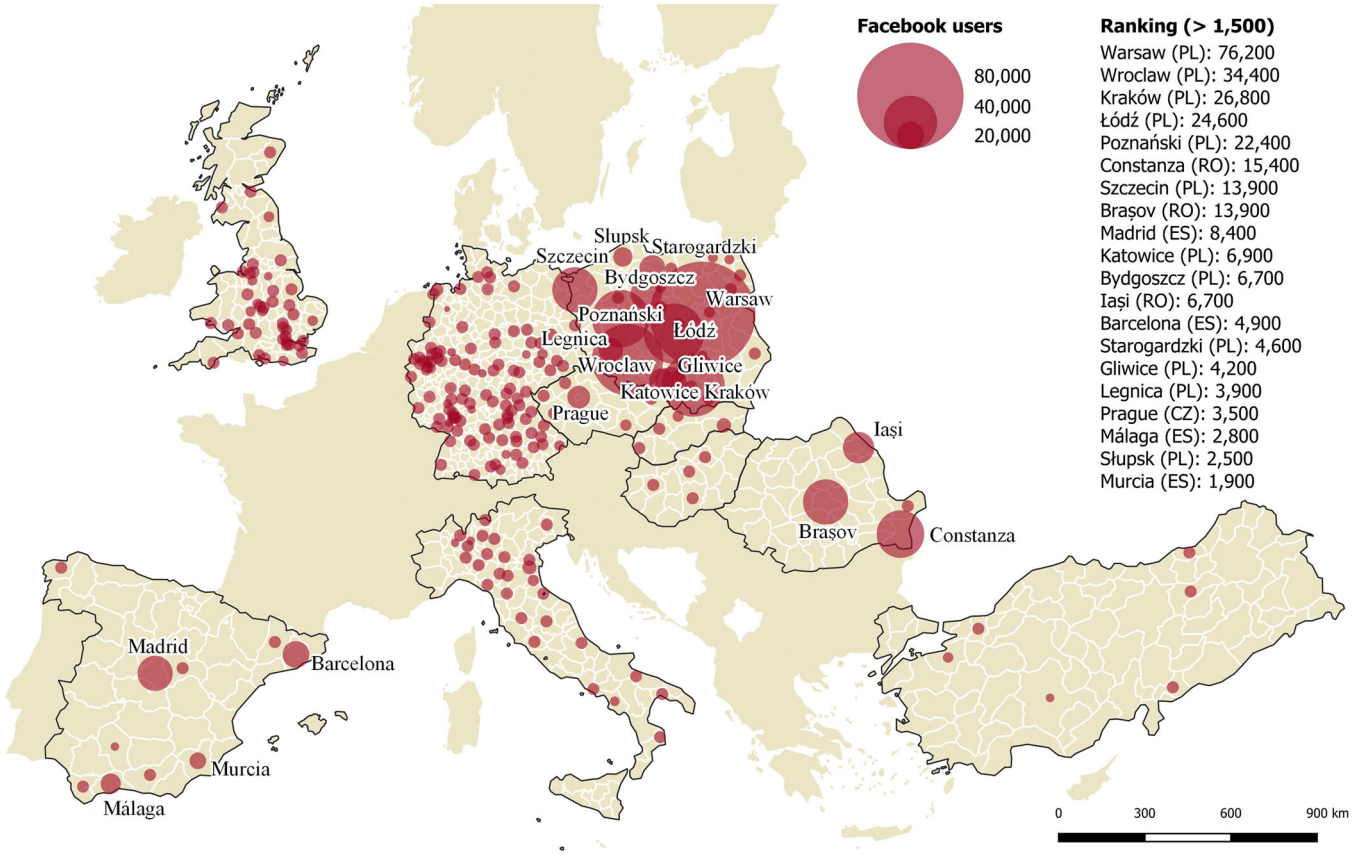

FIGURE 3 Facebook daily active users (DAU) who use Ukrainian as the main language by NUTS 3 regions in countries of interest (median from 28 January 2023 to 12 February 2023).

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as the city with the largest number of Ukrainian-speaking Facebook users, followed by inner and southern Polish regions, including Wroclaw, Krakow Lodz, Poznanski and Katowice and northwest areas, such as Szczecin, Bydgoszcz and Starogardzki. Surprisingly, there are no important settlements in eastern Poland, suggesting that refugees could have used bordering regions with Ukraine preliminarily as transit points.

Outside Poland, the number of Ukrainian-speaking Facebook users is comparatively smaller in size; yet, concentrations still exist. Figure 3 reveals large concentrations in the Romanian regions of Constanza, Brasov and asi, Spanish urban areas of Madrid, Barcelona, Málaga and Murcia and the Czech capital city of Prague. Ukrainian-speaking Facebook users appear to be more equally distributed across areas in southern, western and central Germany, southern and inner England and northern Italy. In Slovakia, Hungary and Turkey, small numbers of speaking Facebook users seem to co-locate in certain regions across these countries. Collectively, results reveal that Ukrainians are highly concentrated in certain regions of Poland and, to a lesser extent, in Spain, Romania and the Czech Republic, while they are equally distributed across space in other countries, such as Germany, Italy or the United Kingdom.

Diasporas are known to be one of the main factors influencing the destination choice among immigrants (Beine et al., 2011; Migali et al., 2018). Therefore, we aim to explore the relationship between the number of Facebook Ukrainian speakers from end-January to mid-February 2023 and the existence of a preexisting diaspora using the Facebook SCI with Ukraine before the Russian invasion. Figure 4 displays a bivariate map and a scatter plot of this relationship. High levels of connectedness in an area indicate a great degree of interaction between people living in this area and those residing in Ukraine before the war. Therefore, we could assume that Ukrainians might have relatives and friends in regions with high levels of connectedness.

Results show a certain relationship between both variables but different settlement patterns across NUTS 3 units. Some areas with a great concentration of Ukrainian-speaking Facebook DAU had high levels of connectedness with Ukraine before the armed conflict, while others displayed moderate levels. Five regions in central, south (Warsaw, Wroclaw, Poznansky, Lodz) and northwestern Poland (Szczecin), and Prague in the Czech Republic display a large number of Ukrainian DAU and also a great degree of connectedness. NUTS 3 regions with a high concentration of Facebook DAU in Romania (Constanza, Brasov and Iasi) and Spain (Madrid, Barcelona, Málaga and Murcia), however, show moderate levels of connectedness as well as certain areas across Poland (Krakovski, Starogardizky, Bydgoszcz, Katowicki and Glwiche). Humanitarian assistance may be needed to supplement the supportive role of migrant social networks in regions with a moderate diaspora. Finally, we identify high levels of connectedness but a moderate concentration of Ukrainian-speaking DAU in four areas western and southern Czech Republic: Karlovarsky, Plzenský, KrajVysocina and Juhomoravský.

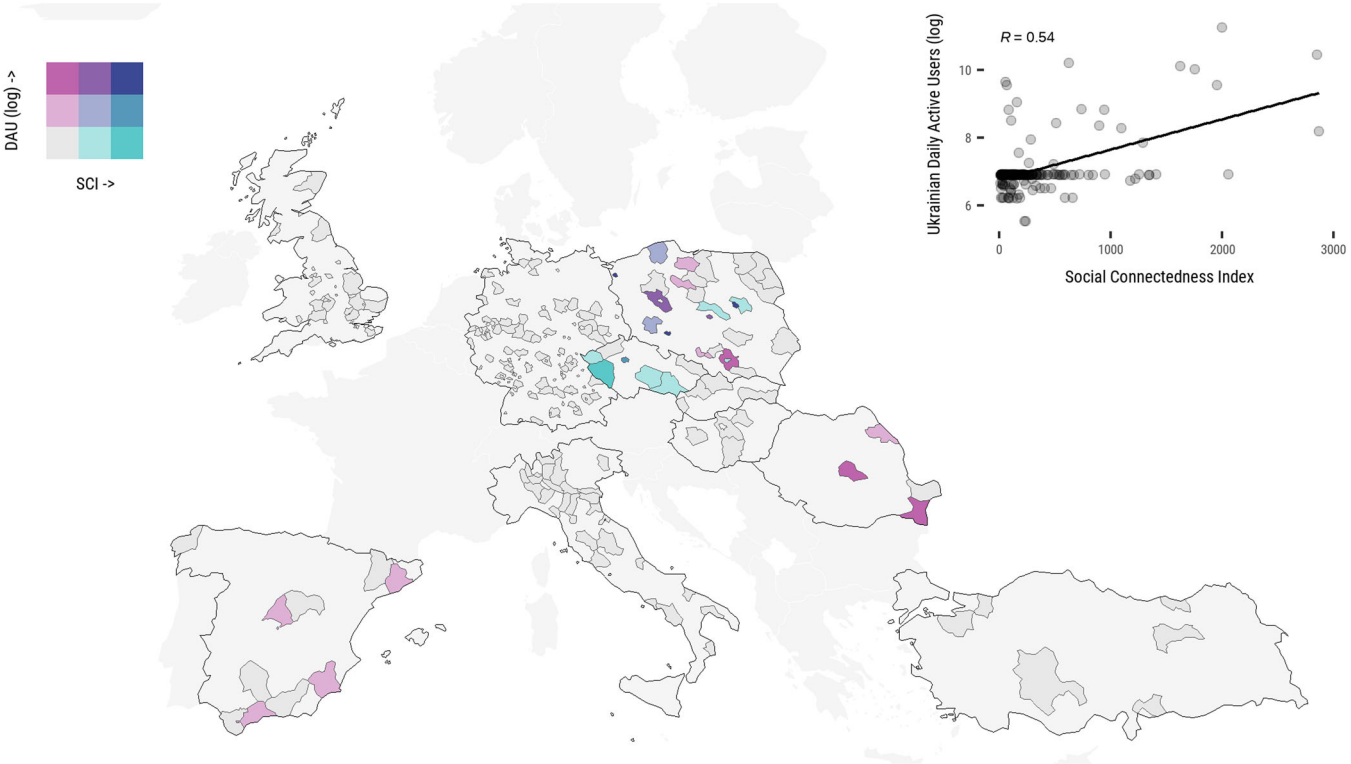

FIGURE 4 Relationship between Facebook daily active users (DAU) who use Ukrainian as the main language (median from 28 January 2023 to 12 February 2023) and the Facebook social connectedness index (SCI) in August 2020.

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This finding might suggest that these areas are not potential settlements of refugees despite having a preexisting diaspora.

4.3 | Determining the associations between the number of Ukrainian DUA and key contextual factors

Next, we seek to understand the association between the number of Ukrainian-speaking Facebook DAU and key contextual factors, including population density, unemployment and the SCI. First, we explore their individual associations before assessing the strength of these relationships using multilevel modelling. The key aim of these analyses is to determine the extent to which the SCI is a strong predictor of the number of Ukrainian Facebook DAU, controlling for key factors.

4.3.1 | Individual associations

We first analyse how refugees are potentially setting across the rural–urban hierarchy, and if they are heading to areas with good employment opportunities. Figure 5 shows the association between the geographic patterns of population concentration among Ukrainian Facebook DAU and population density. We do not find a linear relationship between the number of Ukrainian-speaking Facebook DAU and population density. The association between the count of Ukrainian DUA and population density seems to vary in a nonlinear way across NUTS 3 regions. In Poland, potential settlements are mainly observed in dense large urban agglomerations, such as Warsaw, Wroclaw, Lodz and in Szczecin, and, to a lesser extent, in medium and small size urban regions, such as Krakovsk and Bydgoszcz. The only exception is the rural region of Poznansky, with a large number of DAU. In the Czech Republic, the city of Prague is the primary location of Ukrainians. In Spain, we also identify the main settlements across the largest urban agglomeration of Madrid and Barcelona and in the region of Málaga where the fifth biggest urban area of Spain is located. In Romania, however, Facebook DAU seems to be highly concentrated in regions with low population densities: Constanza and Brasov.

Collectively, results suggest that there are potential concentrations of Ukrainian refugees across large urban agglomerations, medium and small size cities in Poland, the Czech Republic and Spain, while they seem to have settled in rural locations in Romania. Rural areas with large inflows of refugees are likely to require an increase in the provision of services, which are typically scarce in rural locations, to assist a rising number of inhabitants.

Figure 6 displays the relationship between the potential settlement patterns of Ukrainians and unemployment rates, revealing again no lineal association. This association seems to vary across countries. For example, regions with a great concentration of DAU in Poland, the Czech Republic and Romania show low levels of unemployment, while those in Spain are affected by high rates of

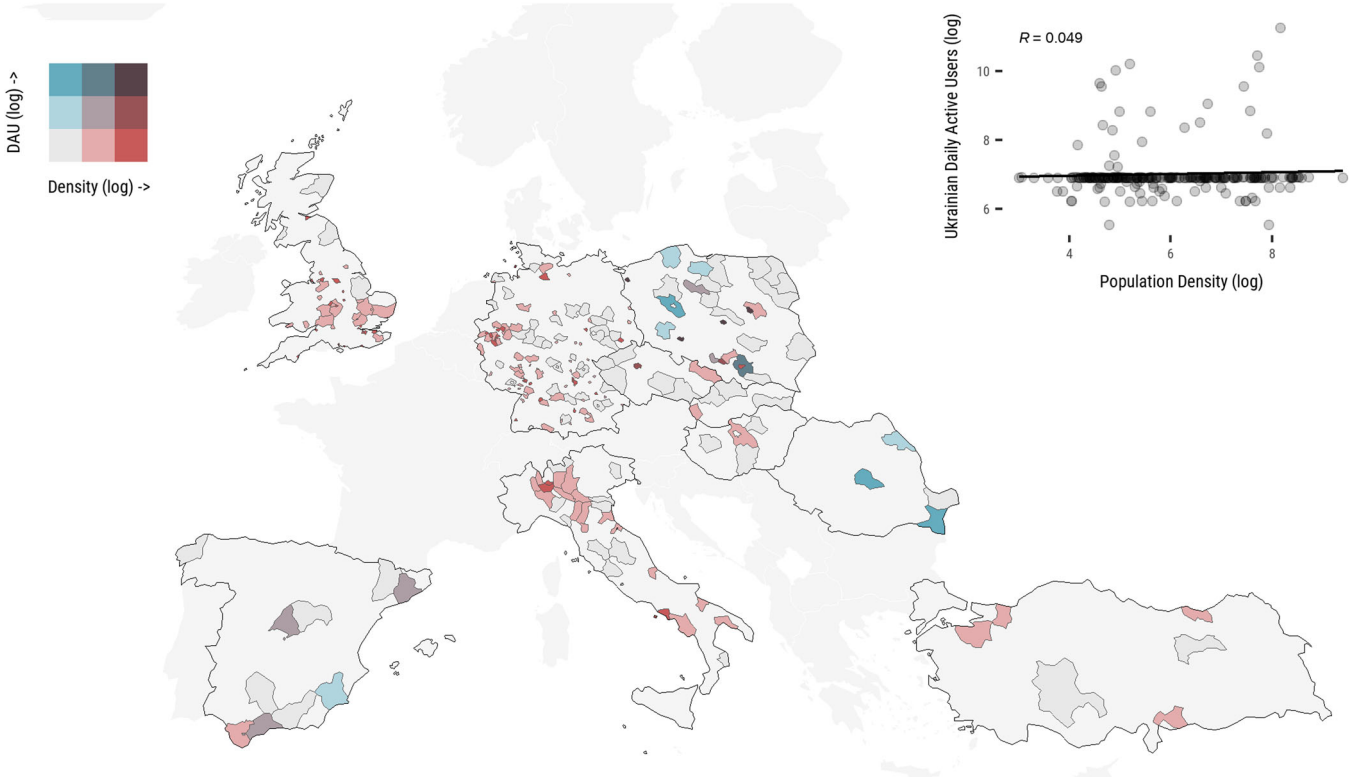

FIGURE 5 Relationship between Facebook daily active users (DAU) who use Ukrainian as the main language (median from 28 January 2023 to 12 February 2023) and population density in 2021.

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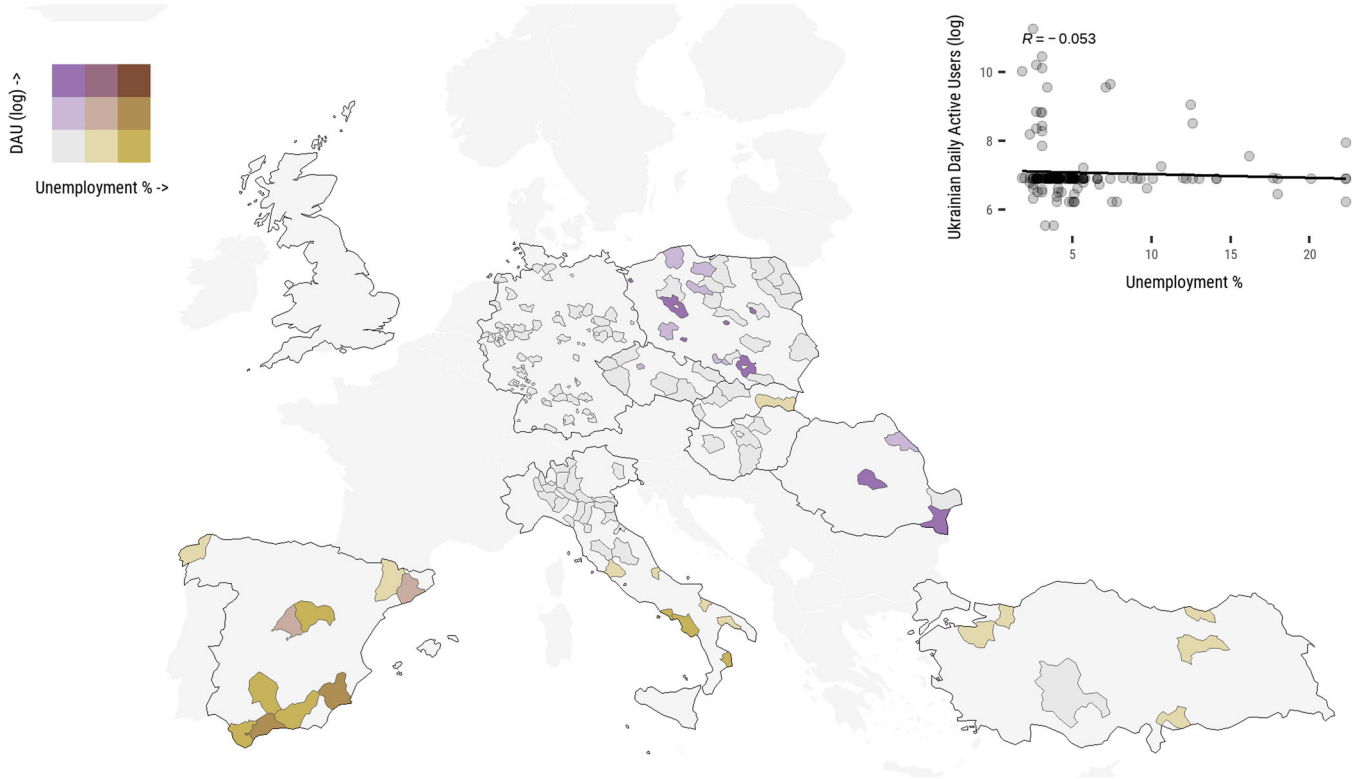

FIGURE 6 Relationship between Facebook daily active users (DAU) who use Ukrainian as the main language (median from 28 January 2023 to 12 February 2023) and unemployment levels in 2021.

unemployment, particularly in the south: Málaga and Murcia. Ukrainian refugees may have experienced difficulties in finding a job in these regions. Labour integration policies should be urgently implemented to facilitate job opportunities for refugees who may be in need of income and self-sustainability.

4.3.2 | Multilevel modelling

We explore the effect of SCI, population density and unemployment rates on settlement patterns in a single multilevel NBRM model. Figure 7 shows the fixed effects and random effects for the model. The coefficients refer to the log of expected counts compared to the reference category. A positive coefficient indicates that an area-level attribute is related to higher levels of DAU, whilst a negative coefficient indicates that an attribute is related to lower levels of DAU. Figure 7a shows the main fixed-effects relationships between key variables and Ukrainian DAU. These results indicate that higher scores of SCI are related to higher numbers of Ukrainian DAU, suggesting that the presence of expansive Ukrainian diasporas may prompt to more refugees to a destination. Unemployment displays no statistically significant results. Despite the no lineal relationship, we observed for population density in the previous section. Our regression results also reveal that while population density is no linearly related to Ukrainian DUA, there is a strong non-linear association with Ukrainian refugees being more likely to move to highly dense population areas. Figure 7b displays the relative importance of the SCI on DAU across the countries of interest. At the country level, we see that SCI has the greatest impact in Italy and Turkey and the weakest impact in Hungary and the United Kingdom, while coefficients for other countries return no statistically significant results.

5 | DISCUSSION AND CONCLUSIONS

We leveraged a combination of nontraditional and traditional data sources to identify and characterise potential settlement areas for Ukrainian refugees across Europe. We found distinctive geographical patterns of population concentration. Ukrainian-speaking Facebook users are highly concentrated in certain urban areas across inner, south and northwest Poland (e.g., Warsaw, Wroclaw, Lodz, Szczecin), Spain (Madrid, Barcelona, Málaga) and the Czech Republic (Prague), while the rural locations in Romania (Constanza and Brasov) seem to allocate a large number users. Ukrainian-speaking users who have settled in other receiving nations (Germany, Italy and the United Kingdom) are more sparsely distributed across the national territory. High concentrations of refugees in rural areas, such as in Romania, are an unusual finding. We presented evidence indicating that Ukrainian refugees are much more likely to be located in large dense urban areas. This finding is consistent with previous work (Duncan & Ioana, 2017; González-Leonardo, 2021; Kılıçaslan, 2016). The arrival

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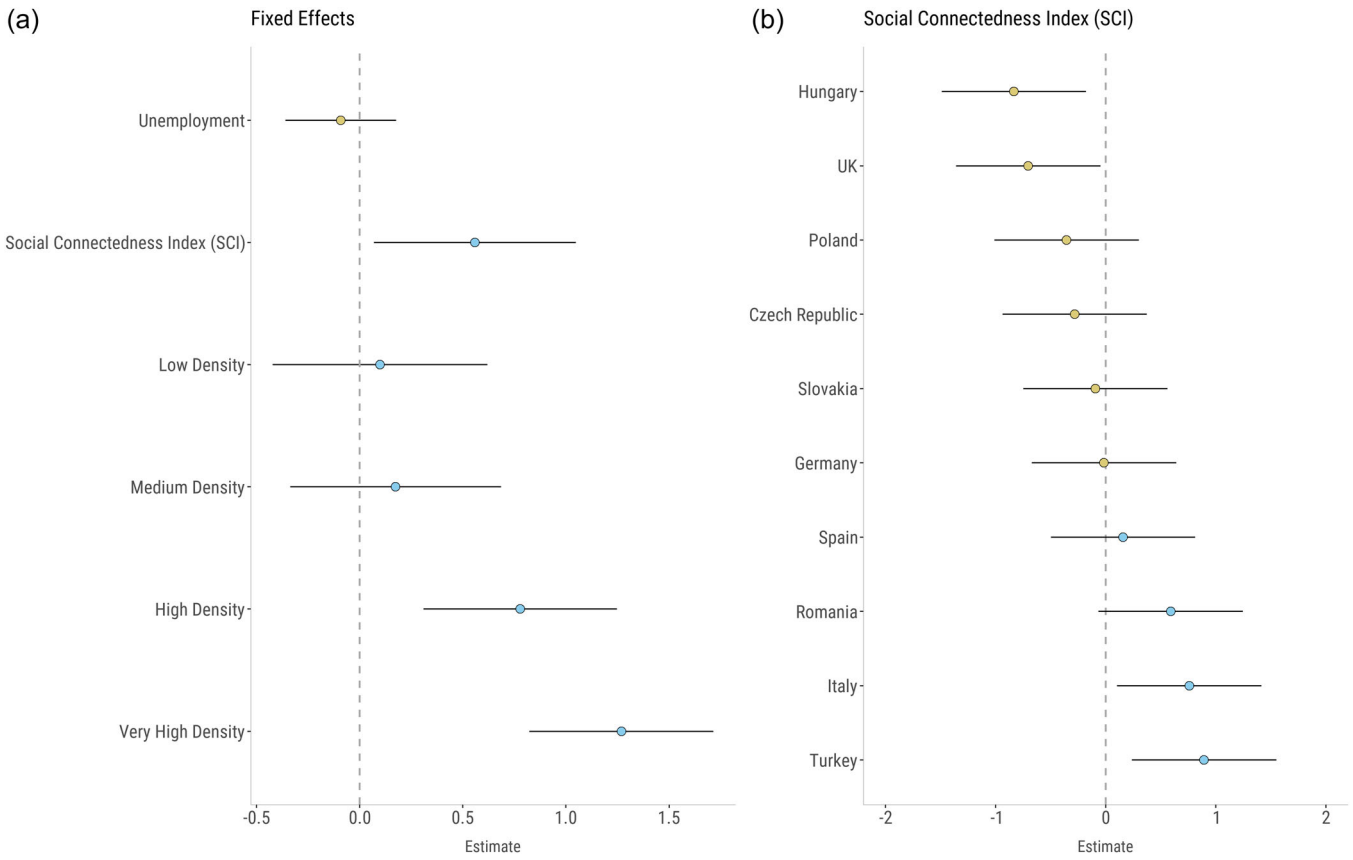

FIGURE 7 Association between social connectedness index (SCI), population density, unemployment and Ukrainian daily active users (DAU): Regression coefficients-main fixed effects (a); Regression coefficients random effects for SCI across countries (b). 'Very low density' is the reference group of population density.

of large inflows of refugees in rural settlements may have led to a significant impact in services demand, such as education and healthcare. Rural areas may lack services and infrastructure to support refugees, neither local institutional structures nor economic capacity to increase service supply. National and European institutions therefore have a key role in providing necessary services and infrastructure to rural areas that are potentially concentrating significant numbers of refugees.

Surprisingly, there are not large concentrations of Ukrainian-speaker Facebook users in bordering regions within neighbouring countries, such as eastern Poland, eastern Czech Republic, northern Slovakia and northern Hungary. This finding suggests that these regions may have been used as transit points by refugees who have moved to inner, southern and northwest Poland, Prague in the Czech Republic, certain rural regions in Romania and non-neighbouring countries, as migration schemes have been implemented to facilitate entry of Ukrainian refugees across Europe (EU, 2022). They may also have returned to Ukraine or been involved in circular migration between Ukraine and Poland or other neighbouring countries. In regions serving as transit points, food, temporary shelter and accommodation centres may be valuable support for refugees in transit.

Our results show a concentration of Ukrainian-speaker Facebook users in certain Spanish regions with high levels of unemployment, especially those in southern Spain where unemployment is particularly high (Málaga and Murcia), coupled with a smaller diaspora than in other receiving areas across Europe. These findings point out an urgent need for labour market integration policies and humanitarian assistance in Spain. Refugees are likely to experience difficulties in finding a job to generate an income and achieve self-sustainability. In addition, some refugees may lack a diaspora to support them in the absence of a job. However, the majority of Ukrainian-speaking Facebook users seem to have gravitated to areas with a healthy labour market across Europe, including Eastern European countries. Such evidence is consistent with commentators anticipating that most Ukrainian refugees are likely to stay in areas where vacant jobs are plentiful and available workers are relatively scarce (Hinshaw & Lovett, 2022). In some of these areas, a previous diaspora of Ukrainians exists, but there seems to be smaller migratory networks in others. Monitoring the labour market integration of refugees is especially important where there is not a diaspora to support them.

Collectively, our findings suggest a varying geographical distribution of Ukrainian refugees across European regions. They also indicate that different packages of humanitarian assistance may be

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needed in different places according to the volume of refugees and the characteristics and capacity of potential settlement areas. In settlements of Spanish cities with high levels of unemployment and moderate diasporas, refugees may need labour market integration policies, subsidies and housing. Settlements with low population densities in Romania may lack services and infrastructures to accommodate a large inflow of refugees. Healthcare and schooling arrangements should be implemented in these areas. In transit points of bordering regions across neighbouring countries, refugees may need temporary assistance.

The UN launched a USD 1.7 billion Refugee Response Plan (RRP) for Ukrainian refugees, which comprises 10 host countries: Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Moldova, Poland, Romania and Slovakia (UNHCR, 2023b). The fund benefits Ukrainian refugees with food, healthcare, cash, labour market integration actions and other life-saving. The RRP plan, however, focuses only on the Easter countries, and sizable amounts of refugees have potentially settled in areas across Western and Shouter Europe as well, where most humanitarian aid should, therefore, come from national governments. The need for humanitarian assistance may be particularly important in settlements with high levels of unemployment across Spain: Málaga, Murcia, Madrid and Barcelona. The national humanitarian package in Spain provides housing, food and a small amount of cash of 400 euros per month (MISSM, 2022), but lacks specific measures to assist refugees' labour market integration. Therefore, additional measures of labour market integration should be implemented in the Spanish settlements to generate income and achieve self-sustainability among refugees.

Our analysis demonstrates the value of digital footprint data to provide near-real-time monitoring of a rapid unfolding crisis resulting from the war in Ukraine. Yet, these data are an unintended consequence of administrative processes (Arribas-Bel et al., 2021). They tend to be locked in-house and need to be reengineered for scientific research (Rowe, 2023). Access to data is restricted for ethical and privacy considerations. Yet, successful data-sharing frameworks to grant access to data have started to proliferate. Meta's Marketing API and Meta's Data for Good initiative are good examples of reengineering data to ensure privacy, anonymisation and confidentiality before making them available. However, these data also have challenges and limitations. A key limitation is that the Facebook API only allows downloading real-time data. We were, therefore, unable to compare the current spatial concentration of Ukrainians across Europe to that before the Russian invasion of Ukraine.

A second challenge is that we could not measure the actual number of Ukrainians. Not all individuals have a Facebook account. Only about 36% of the Ukrainian population has an account (Kemp, 2023), and Facebook usage is lower among children and old populations (Gil-Clavel & Zagheni, 2019; Hargittai, 2020). An estimated 5% of Facebook accounts are fake (Naprys, 2023). Facebook usage differs by sex (highest coverage among women) and between Ukrainians from urban and rural areas, with the highest penetration for individuals from Kyiv (Kemp, 2023). Additionally, we identified the Ukrainian population as Facebook DAU who use Ukrainian as the main language. Some of users may use a different primary language [e.g., English, Russian- around 20% of Ukrainians (Official website of Ukraine, 2022), or the host-country language]. The presence of biases in Facebook data may have thus had an impact on our results due to the over- or under-representation of the Ukrainian population groups on Facebook. Yet these effects are challenging to quantify without a comparative ground truth data set.

Despite these limitations, our results provide valuable and useful information on the potential spatial concentration of Ukrainians across European regions. Future lines of research could seek to address the actual number of Ukrainians refugees at the subnational levels when register data becomes available. Our findings also provide knowledge of the type of potential regions attracting Ukrainians and point out issues that refugees could experience according to different regional characteristics. Surveys and qualitative research could provide additional information to complement our results from an individual perspective.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analysed in this study. All code to replicate our analyses is provided on a Github reporistory: https://github.com/fcorowe/iom-article.

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