Sensing Population Displacement from Ukraine Using Facebook Data: Potential Impacts and Settlement Areas*

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Abstract

The escalation of conflict in Ukraine has triggered the largest refugee crisis in Europe since WWII. As of 17 August 2022, over 6.6 million people have fled Ukraine. Large-scale efforts have been made to collect data and measure the scale of forced population displacements, and identify the major receiving countries of these population flows. Current evidence has thus focused on providing a country level representation of the unfolding refugee crisis. Less is known about the subnational patterns of population displacement within Ukraine, and potential subnational settlement areas of the continuous flow of Ukrainian refugees in major receiving countries. Highly granular geographical data in real time are critical to these ends to ensure the appropriate delivery of humanitarian assistance where it is most needed. Drawing on digital trace data from Meta-Facebook, this paper aims to identify and assess the potential settlement areas and impacts of population displacements on the demographic and economic structures of sub-national communities within and outside Ukraine. We reveal large population losses in eastern, southern and northern Ukraine, particularly Khersonska (59%), Kharkivska (55%) and Kyiv (45%), and gains in western areas, specially in Livivska (16%). We also find reductions in female and young populations across the country, and increases in male and older populations in central and western regions. We identify likely settlement areas in some countries (Poland, Czechia, Slovakia, Hungary, Italy, Germany and Spain), noting that Ukrainian refugees are less likely to remain in countries which have recorded large refugee influxes but lack of local social networks, such as Romania and Turkey. We also reveal the potential impact of refugees moving to areas with old population structures and low unemployment. Yet, these impacts appear to differ across countries.

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1. Introduction

The escalation of armed conflict in Ukraine on 24 February 2022 has triggered the largest refugee crisis in Europe since WWII (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. As of 17 August 2022, nearly one-third of Ukrainians are estimated to have been forced from their homes (UNHCR 2022b). Over 11 million border crossings from Ukraine into neighbouring countries have been recorded since 24 February 2022 (UNHCR 2022b), and a large yet undetermined number of people are expected to have been forced out of the home within Ukraine.

Displaced populations are in the need of protection and humanitarian assistance to ensure their safety, overall health and well-being. They require food, shelter, financial aid and healthcare to meet basic necessities, and access to employment and education to generate an income and achieve self-sustainability (UNHCR 2022a). Population displacements also entail impacts on receiving societies involving an increased demand for housing, food and public services, including schools and healthcare facilities. Displaced populations can also help mitigating the effects of ageing and reduced fertility levels in host societies at least temporarily (Newsham and Rowe 2019; Backman, Lopez, and Rowe 2020). Highly granular geographical data in real time are critical to identify and assess population displacement impacts on host settlement areas where increased service demand is expected, in order to 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 characterised by slow data collection and release. 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, but also of return movement into Ukraine (UNHCR 2022b). However, little is known about the sub-national patterns and impacts of population displacement within Ukraine and other countries. Digital trace data have emerged as a key source of information, offering an opportunity to capture human population movements at highly granular geographical and temporal scales multiple countries (Rowe 2021).

Drawing on data from Meta-Facebook, this paper aims to identify and assess the potential settlement areas and impacts of population displacements on the demographic and economic structures of sub-national communities within and outside Ukraine. Specifically, we seek to address the following questions:

- How have local population structures within Ukraine changed since the start of the invasion? What areas have gained or lost population? And how these gains and losses have changed over time?

- What are the main potential settlement areas of Ukrainian refugees in the need of humanitarian aid within main receiving countries?
- What are the likely demographic and economic impacts of Ukrainian refugee migration on potential settlement areas in these societies?

The next section offers a brief overview of the current knowledge of population displacements within and outsite Ukraine in terms of scale and demographic impacts. Then we describes the methods and data used for our analysis before presenting the results. Finally we summarise our key findings and discuss potential implications.

2. Background

The escalation of conflict in Ukraine has triggered a mass exodus since 24 February 2022. As of 17 August 2022, UNHCR estimates that over 6.6 million refugees (UNHCR 2022b). Early reports estimated that around 90% of refugees were women and children (Ramsay 2022). More than 3.8 million have registered for temporary protection or similar national protection schemes (UNHCR 2022b). More than 11 million movements out of Ukraine have been recorded, and over 4.7 million have moved back into the country (UNHCR 2012). Reportedly the number of border crossing out of Ukraine have declined after a peak in March, while movements into Ukraine increased as the conflict shifted its focus towards eastern and southern regions away from Kyiv (UNHCR 2022c). Border crossing movements have been noted to be pendular (UNHCR 2022c). 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 via neighbouring countries on its west boarder. Poland has been a main receiver of refugees from Ukraine. As of 17 August 2022, Poland recorded over 1.2 million Ukrainian refugees (UNHCR 2022b). Large numbers of refugees have also been recorded in other neighbouring countries: Moldova (89+ thousand), Slovakia (87+ thousand), Romania (84+ thousand) and Hungary (28+ thousand) (UNHCR 2022b). The number of refugees staying in these countries have decreased as special migration schemes have been developed to facilitate entry of Ukrainian refugees into other countries in Europe (EU 2022). Observers have anticipated that most refugees are likely to stay in Poland and other central European countries because of *tight* labour market conditions[1], relatively affordable cities and a pre-existing diaspora in these countries (Hinshaw and Lovett 2022).

However, most population has remained within Ukraine. Large-scale population displacements are thus expected, particularly in eastern and southern areas of the country on the frontline and in the early months of the invasion around Kyiv. Yet, scarce information exists to quantify and identify the location of the over 37.2 million Ukrainians remaining in the country. Leasure et al. (2022) recently developed population estimates from digital

[1]Broadly defined a labour market is said to be *tight* if vacant jobs are plentiful and available workers are relatively scarce (Brigden and Thomas 2003).

trace data from Meta-Facebook to monitor population displacement in Ukraine. As of 10 May 2022, they estimated that over 6.5 million people had been displaced from their oblast of residence in 2020.

Thus, while existing analyses have provided an understanding of the scale and receiving countries of Ukrainian refugees, evidence has focused on offering a country level representation. Less is known about the subnational patterns of population displacement within Ukraine, and potential subnational areas of settlements of refugees moving out of the country. Such information is critical to ensure the provision of humanitarian assistance where is needed the most.

3. Data and Methods

Our analysis comprises three stages.

3.1. Subnational population changes within Ukraine

To analyse population changes across subnational areas within Ukraine, we leveraged on a dataset of population estimates produced by Leasure et al. (2022) based on *Facebook marketing API data* (Meta 2022a). The dataset contains daily sub-national population estimates of population size disaggregated by five-year age group and gender. The data cover all oblasts in Ukraine, except for Crimea as Facebook data were not available for this area. Oblasts represent the primary administrative units in Ukraine - which is equivalent to states in the US or regions in the UK. The dataset also includes population estimates for 2020, in order to provide a baseline period to monitor changes in population changes over time. The estimates were adjusted to account for changes in Facebook use over time. Yet, accounting for these changes is challenging. The estimates are likely to still contain an indeterminate amount of noise. They may also be seen as over-estimating changes in local populations as the baseline period covers the first year of the COVID-19 pandemic. Though, if we consider that the estimates capture night-time resident population, the effects of using this year are expected to be small relative to population changes caused by the escalation of the armed conflict. The estimates are also affected by power outages in the Donetsk and Luhansk regions resulting in zero or small numbers for certain dates (Leasure et al. 2022). Rather than focusing on daily changes, we sought to mitigate this issue by examining weekly percentage changes in population between the baseline and individual weeks following the start of the invasion since 5 March to 25 June 2022. We analysed changes in total population and changes by age group and gender.

3.2. Potential settlement areas outside Ukraine

To identify potential refugee settlement areas in receiving countries outside Ukraine, we performed two analyses. First, we sought to establish the relationship between the size of Ukrainian refugee influx and the size of Ukrainian citizen population residing in receiving

societies at the country level. We expected to find a positive correlation. Countries with larger Ukrainian diasporas were expected to be absorbing greater numbers of refugees. To this end, we used refugee data from the UNHCR Ukraine Refugee Data Portal (UNHCR 2022b). We used population counts dating to 22 August 2022 and identified as "refugees from Ukraine recorded in country" on the portal. Data on population counts on Ukrainian citizenship living in 28 European countries were obtained from Eurostats (data product: `migr_pop1ctz`).

Second, we sought to identify potential settlement areas within receiving countries. Subnational level data on refugee were not available so we triangulated traditional and non-traditional sources of information. We integrated four different data sources: (1) Facebook population; (2) Facebook Social Connectedness Index (SCI) (Bailey et al. 2018), (3) Ukrainian citizenship, and (4) Population density data (Figure (**ref?**)(fig:fig1)). Intuitively we sought to define potential settlement areas for Ukrainian refugees by identifying areas with comparatively large population increases, higher social connectivity with Ukraine, and a large existing Ukrainian diaspora. We know that diasporas are an important predictor of the settlement areas for migrants (Beine, Docquier, and Özden 2011). Additionally we considered population density data area as large urban agglomerations tend to be the primary settlement areas for migrant communities (Duncan and Popp 2017). We sought to identify the type of settlement as anecdotal reports suggest that Ukrainian refugees have settled in rural locales (Zavialova 2022). Our geographical units of analysis were NUTS3 regions.

The Facebook population and SCI data were built by Meta from information from users who shared their location history. The data were accessed via their Data for Good Initiative (`https://dataforgood.facebook.com`). We note that Facebook discontinued the population data used in this paper. They were discontinued on 22 May 2022 after this project has started. We used data for the week 12-19 May 2022 to quantify population change across NUTS3 regions. Specifically, we measured changes in Facebook population between the average population during the last week of available data (12-19 May 2022) and a week in January before invasion (13-20 January 2022). We used the SCI as a proxy for Ukrainian diasporas. 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 subnational areas in European counties with Ukraine. Population counts on Ukrainian citizenship for NUTS 3 regions were obtained from Eurostat (data product: `cens_21ua_a5r3`). Population density data were extracted from the Global Population Settlement layer 2020 produced by the European Commission, Joint Research Centre (Schiavina et al. 2022).

3.3. Potential impacts on subnational areas

We also sought to understand the potential impacts of refugee inflows on local areas. We analysed the association between existing levels of unemployment, ageing and local population changes in countries absorbing large flows of Ukrainian refugees and extensive Ukrainian diasporas at the NUTS3 level. These countries include Czechia, Germany, Italy, Spain, Poland,

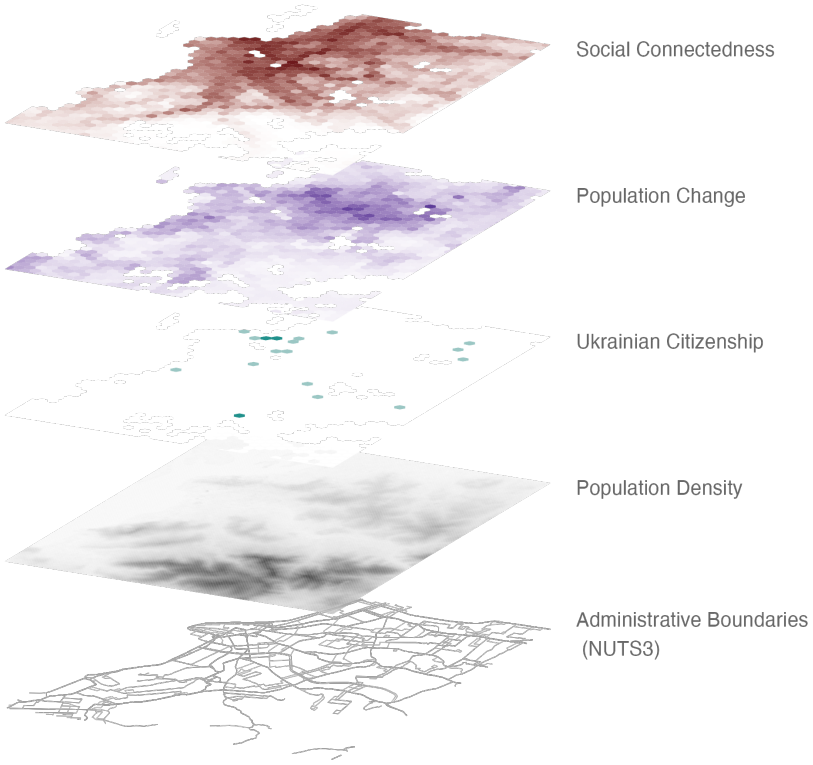

Figure 1. Integration of subnational level data.

Portugal, Hungary and Slovakia. As described above, we measured changes in population across NUTS3 areas using Facebook population data by computing the difference between the average population during the last week of available data (12-19 May 2022) and a week in January before invasion (13-20 January 2022). To measure impacts on population ageing, we used 2021 population count data from Eurostat (data product `demo_r_pjanaggr3`). We computed the share of population aged 65 and older. To measure impacts on unemployment levels, we used 2021 unemployment rate data from Eurostat (data product `lfst_r_lfu3rt`).

4. Results

4.1. Population displacement from eastern, southern and northern to western Ukraine

Figure 2 reports estimates of the percentage change in population between the baseline population in 2020 and 25 June 2022 across Ukraine based on Facebook data. It reveals large changes in local population structures. Population increases are observed in regions bordering Poland, Slovakia, Hungary, Romania and Moldova, and reductions in population in central, eastern and southern Ukraine in areas, suggesting a main pattern of population displacement towards western Ukraine. The largest declines in population are observed in Khersonska (59%), Kharkivska (55%) and Kiyv (45%), where intense fighting has taken place, and to a lesser extent in neighbouring regions (23-31%). Chernivetska (18%) and Vinnytska (11%) registered the largest percentage population increases, while Lvivska reported the greatest rise in population numbers. These increases are likely to reflect large amount of transitory population movements and the function of these regions as access points to neighbouring countries.

4.2. Evolving changes in local population size and structures

Population changes has reflected the timeline of the conflict. Figure 3 shows weekly percentage population changes between the baseline population in 2020 and the weekly population average since 1 March 2022. Figure 3.a displays percentage changes in overall population numbers, revealing the tempo of population displacement across Ukraine. It shows decreasing population decline in Kyiv and neighbouring areas (Kyviska and Chernihivska), reflecting large population losses during the concentration of fighting in these areas during March-April, and less pronounced population losses from May as some people returned home or sought shelter, and the frontline was intensified in eastern Ukraine. Figure 3.a reveals that population losses in Kharkivska and Khersonska have been more intense in later months, and that population increases in western Ukrainian regions were more prominent during the early months of the conflict. During more recent weeks in June, population increases in western Ukrainian were more moderate, though they are still notable in some oblasts representing over 30% rises in population. Limited changes are observed in Poltavska and Rivnenska.

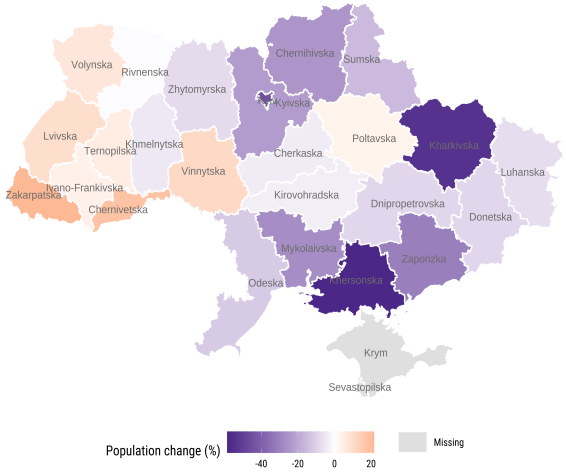

Figure 2. Population changes across Ukrainian oblasts, 2020 and 25 June 2022. The maps are for illustration purposes only. The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the International Organization for Migration.

These shifts in population size have occurred together with large changes in age and gender population structures. Figures 3.b-c reveal the gender imbalance of population changes. Reductions in female population occurred across the country, except for the western regions of Zakarpatska and Chernivetska. By contrast, rises in male population are recorded across most of central and western Ukraine. Though, regions experiencing high concentration of fighting also registered large population losses. Differences across age groups are also apparent. Figures 3.d-h reveal that population losses across Ukraine reflect the shrinking of young populations, while increases mirrored growth of older populations, particularly people aged 25-54. These contrasting patterns in gender and age reflect the existing martial law enacted in 24 February prohibiting male Ukrainian citizens age 18-60 from travelling aboard, and the fact that female and children comprise the main groups of Ukrainian refugees.

4.3. Identifying potential settlement areas in host countries

As indicated, the escalation of the conflict in Ukraine has triggered a refugee exodus of 6.6 million people, with Poland, Germany and Czechia collectively absorbing almost 40% of all refugees. Yet, we know less about where refugees are settling in host societies. We sought to identify potential settlement areas by integrating and analysing four sources of information: (1) the size of Ukrainian citizen population or Ukrainian diaspora; (2) population change between our pre-war baseline and post war period (i.e. 12-19 May 2022); (3) population density; and, (4) the degree of Facebook social connectedness as captured by the SCI described in Section 3. We analysed the associations between these sources at the NUTS3 level. We

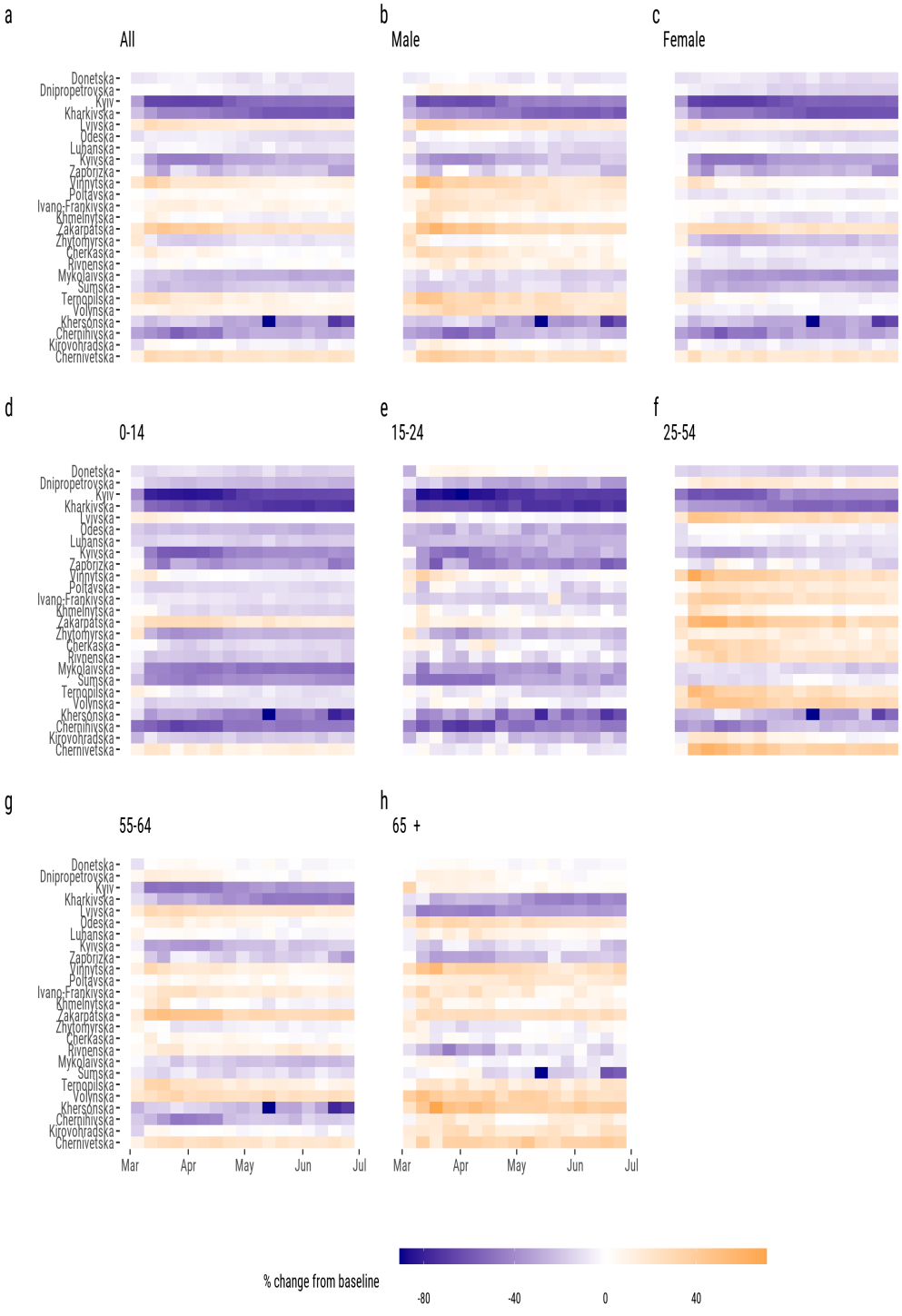

Figure 3. Weekly population change across Ukrainian oblasts by gender and age group, 2020 and 25 June 2022. Areas are organised by population size from the largest to the smallest in 2020.

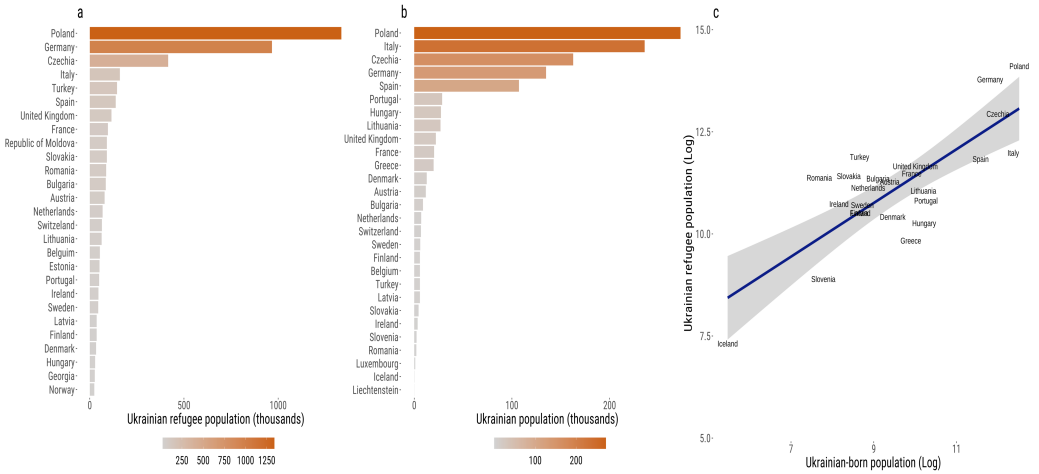

Figure 4. a. Ukrainian refugee population count by destination country, 22 August 2022 (Source: UNHCR). b. Ukrainian citizenship population count by country, 2021 (Source: Eurostat). c. Ukrainian refugee population count vs. Ukrainian citizenship population.

expect the geographical co-occurrence of high recordings of Ukrainian diasporas, population rises, population density and social connectedness between subnational areas in receiving countries with Ukraine to be good predictors of potential settlement areas.

To establish some grounding, Figures 4.a-c display the country-level association between the size of the current Ukrainian refugee influx and the size of the local Ukrainian citizen population for European countries. They show a strong positive association reflecting that countries with more extensive communities of Ukrainian-born populations have been attracting the largest influxes of Ukrainian refugees, such as Poland, Germany, Czechia, Italy and Spain. By contrast, countries with a smaller Ukrainian diaspora have registered a more moderate influx, including Iceland and Slovenia. The relationship is however not linear and some countries, such as Turkey, Slovakia and Romania with a relatively small Ukrainian diaspora 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.

Figure 5.a displays the relationship between the size of the local Ukrainian citizen population and the SCI across NUT3 regions for Belgium, Spain, Finland, Norway, Luxembourg and Portugal. It reveals a positive association suggesting that Ukrainians living in Ukraine tend to have strong social connections with places with larger diasporas of Ukrainian migrants. However, we could not confirm this finding for all the countries in our sample as aata on Ukrainian diasporas at the NUTS3 level are only available for a few countries. So we analysed the association between the SOI and changes in local populations between a pre-war and post war period across NUTS3 regions in Europe as captured by Meta-Facebook to complement these findings (see details in Section 3). Figure 5.b reports the results displaying a positive

relationship and indicating that areas with higher social connectedness have tended to register larger rises in population numbers, but little changes elsewhere. While our analysis does not identify the causes of these increases, the findings suggest that rises in population numbers in areas of high social connectedness with regions in Ukraine are likely to reflect potential settlement areas for Ukrainian refugees.

Figure 5.c-d show the association between the geographic patterns of population change, social connectedness and population density for Ukraine's neighbouring countries and countries with large Ukrainian diasporas. The emerging picture reveals areas of high social connectedness with Ukraine and large population increases since the start of the war, identifying potential locations of settlement for Ukrainian refugees. These areas cover most of Poland, Czechia, Slovakia and Hungary, northern and central Italy, including large urban agglomerations, medium size cities and rural locations. In Germany and Spain, they are scattered across the country mainly comprising urban areas. In Germany they include the metropolitan area of Berlin and Frankfurt as well as cities, such as Dresden, Leipzig and Cologne. In Spain, they comprise large cities like Madrid and coastal cities (Murcia and Málaga).

Figure 5.c-d show an overall pattern of comparatively low scores of social connectedness and population change in Romania and Turkey. Only a few areas display population increases coupled with low scores of social connectedness with Ukraine suggesting that refugees may be using these countries as transit points because of their geographical proximity. Local social networks of support for Ukrainians in these countries appear to be limited. Increased levels of humanitarian assistance may be needed to supplement the supportive role of migrant social networks if Ukrainians are deciding to stay put.

4.4. Assessing potential local impacts

We also examined the potential impacts of Ukrainian refugee flows on local economic and demographic structures across eight countries (Czechia, Germany, Italy, Spain, Poland, Portugal, Hungary and Slovakia). We focused on countries absorbing large numbers of refugees and displaying a large Ukrainian diaspora. Sizable refugee inflows could be expected to mitigate local population ageing or losses, but also put increasing pressure on local economies, particularly in high unemployment areas. We explored the potential impacts on existing ageing and unemployment levels. We cannot directly measure these impacts at the subnational level because of lack of data on Ukrainian refugees. So we analysed changes in population as captured by Facebook data. Particularly we focused on the impacts on the potential settlement areas of Ukrainian refugees highlighted in Figure 5 - displaying unusually high increases in population and social connectedness. Specifically we analysed the association between the share of population aged 65 and over, unemployment rates and percentage changes in population. As above, we measured population changes between pre (13-20 January 2022) and post war (12-19 May 2022) periods.

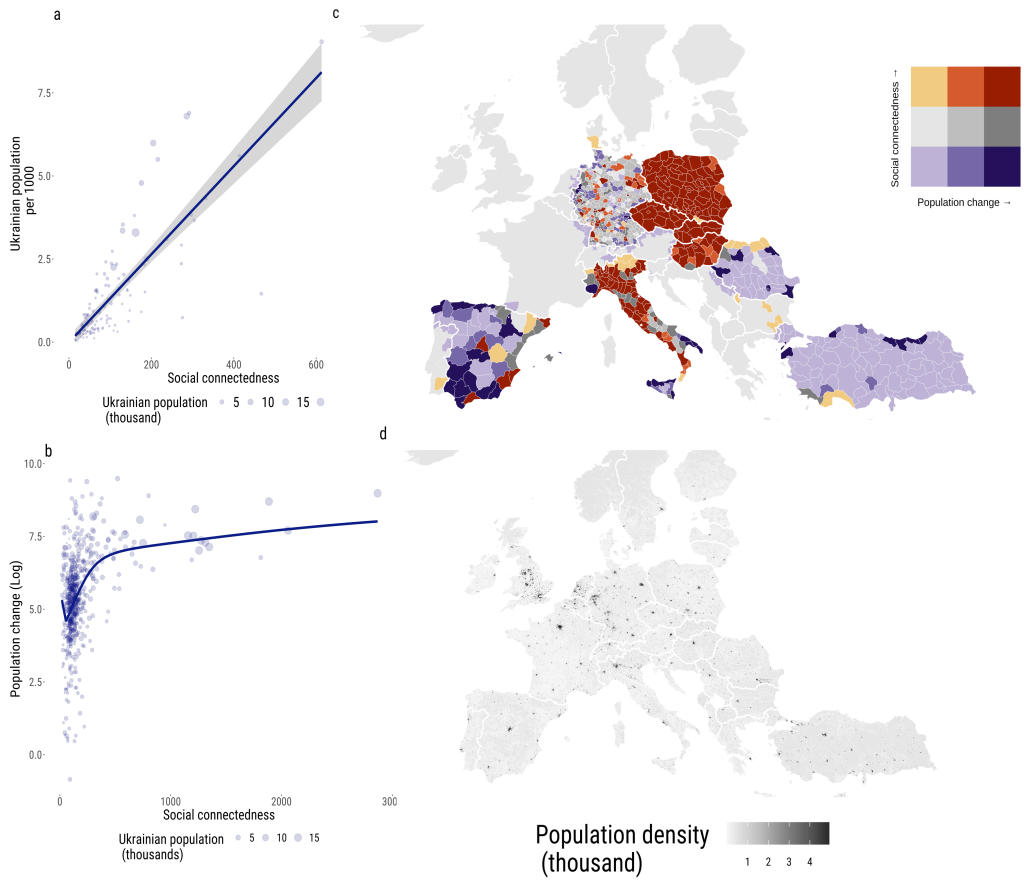

Figure 5. a. Ukrainian citizenship population vs. Facebook social connectedness index (Data source: Eurostat; Meta-Facebook). b. Relationship between population change between pre (13-20 January 2022) and post war (12-19 May 2022) periods vs. Facebook social connectedness index (Data source: Meta-Facebook). c. Map of population change vs. Facebook social connectedness index (Data source: Meta-Facebook). b. Map of population density (Data source: EU-JRC). The maps are for illustration purposes only. The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the International Organization for Migration.

Figure 6 reveals a pattern of high variability across countries. Population rises range from less than 2% to 18% across potential settlement areas. We also observed variations in the extent and direction in the association between the local share of population age 65+ and percentage population change. Countries with older population structures tend to display contrasting patterns. Germany, Portugal and Spain show negative correlation coefficients reflecting that areas characterised by younger population structures have tended to experience large percentage increases in population. This pattern suggests that inflows of Ukrainian refugees may not help mitigating the effects of local population ageing, but they may preserve young age structures in urban areas at least in the short-term. In Italy, a positive correlation suggests that population changes are occurring in areas characterised by older population structures alleviating at least temporarily the local effects of ageing. In countries with comparatively younger populations, Czechia, Hungary, Poland and Slovakia, population rises seem to be occurring more uniformly across the country and also reflect a more balanced local representation of the population aged 65 and over.

Figure 7 shows a pattern of negative and moderate association between local unemployment levels and population change. This pattern suggests that larger population increases are occurring in potential settlement areas with relatively low unemployment levels. Additionally, this pattern may also reflect relatively low national unemployment levels in Czechia (3.3%), Hungary (3.3%) Poland (4.9%), Germany (5.4%), Portugal (5.7%) and Slovakia (6.2). Though, large population increases also seem to be happening in potential settlement areas with high pre-existing levels of unemployment in particular regions in Spain and Italy where national unemployment levels are comparatively higher. While these regions seem to correspond to large urban and coastal areas in Spain such as Madrid, they also involve rural areas in northern Italy. Refugees settling in sparsely populated rural areas may require special assistance finding suitable jobs as they are likely to lack the required institutional structures to the efficient delivery of humanitarian assistance.

5. Conclusions

The UNHRC has made valuable efforts to produce data and offer a country-level representation of the unfolding Ukrainian refugee crisis. However, less is known about the subnational dynamics of population displacements within and outside Ukraine. This paper aimed to measure and analyse the extent and subnational patterns of population changes in Ukraine; identify potential refugee settlement areas across Europe; and, assess the potential impacts of population displacements on unemployment and population ageing in primary destination countries.

We revealed a general pattern of population displacement from eastern, southern and northern to western Ukraine. The largest declines in population were observed in Khersonska (59%), Kharkivska (55%) and Kyiv (45%) where fierce fighting has taken place. Regions on the Ukrainian western border recorded the greatest rises in population. Yet, the magnitude of these increases have tended to decline during the course of the war. We showed evidence of

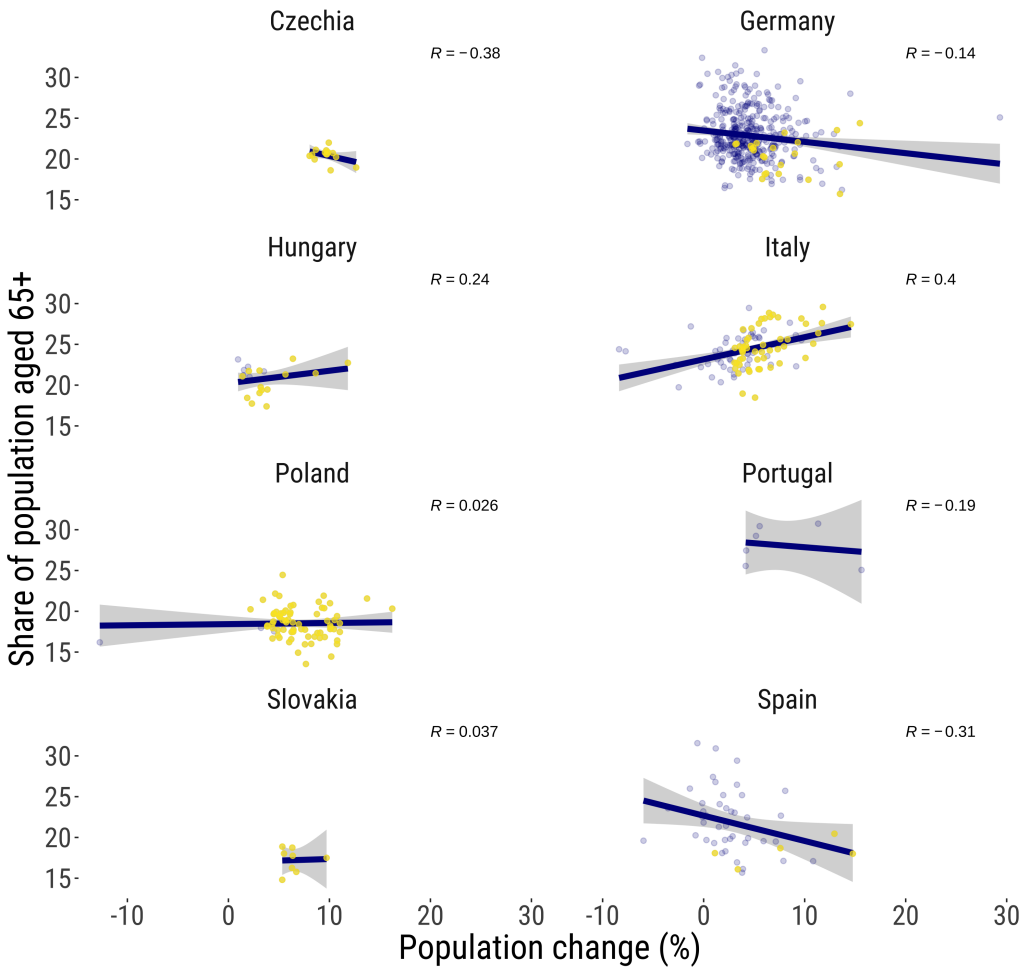

Figure 6. Share of population aged 65+ vs. percentage population change between between pre (13-20 January 2022) and post war (12-19 May 2022) periods. NUTS3 regions highlighted in yellow correspond to the potential settlement areas identified in Figure 5.

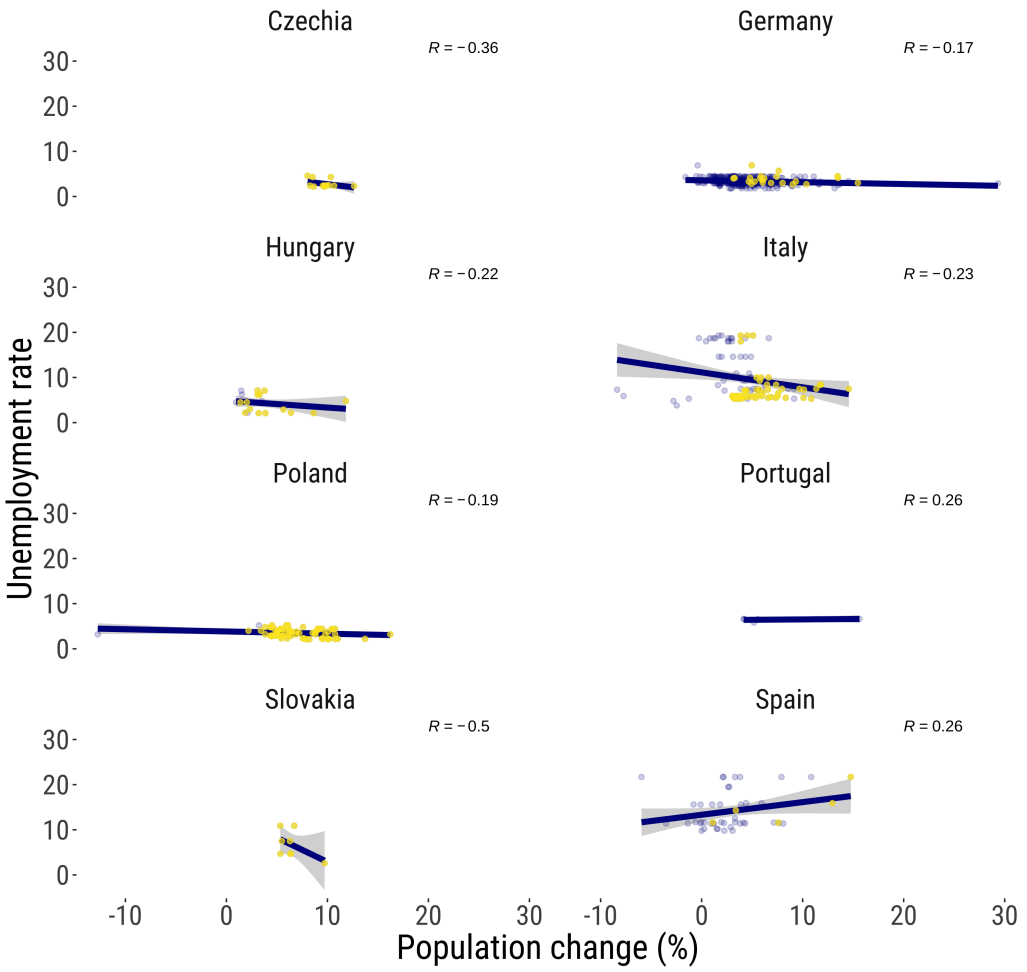

Figure 7. Unemployment rate vs. percentage population change between between pre (13-20 January 2022) and post war (12-19 May 2022) periods. NUTS3 regions highlighted in yellow correspond to the potential settlement areas identified in Figure 5.

population returning to Kyiv and neighbouring areas as the frontline of the fighting refocused to eastern and sourthern Ukraine in May-April. Reductions of female and young (aged 0-24) populations were recorded across the country, while increases in male and older populations were more intense in central and western regions. Taken together, these findings suggest that humanitarian assistance should concentrate on the western and central regions of Ukraine and aim to target at three distinctive groups: (1) females and children intending to leave the country; (2) families and particularly males forced to leave their home and relocate elsewhere within Ukraine; and, (3) families seeking to return to Kyiv and neighbouring regions. Identifying these groups is important as the level, type and duration of required assistance is likely to differ.

In the absence of suitable subnational level data, we leveraged on the triangulation of traditional and non-traditional data to identify potential settlement areas for Ukrainian refugees in destination countries. We argued that areas displaying unusually large population increases and high levels of social connectedness with Ukraine were likely to represent potential areas of settlement for Ukrainian refugees. We thus identified that extensive areas in Poland, Czechia, Slovakia and Hungary, northern and central Italy, and a very specific cities in Germany and Spain are likely to constitute potential settlement areas. By contrast, despite recording large influxes of Ukrainian refugees to date, no area in Romania and Turkey displayed unusually large population increases and high levels of social connectedness with Ukraine, suggesting that these countries may represent transitory stops for refugees. These findings also suggest that different packages of humanitarian assistance may be needed (EU 2022). In countries providing more permanent settlements, long-term housing, jobs, health care and schooling arrangements may need to take priority. In countries serving as transition points, food, temporary shelter and large accommodation centres may be more valuable support refugees in transit.

We also presented evidence of the potentially distinctive impacts of refugee inflows on population ageing and unemployment in countries absorbing large numbers of refugees and with large Ukrainian diasporas. In Italy, a positive correlation between changes in local population and the share of people aged 65 and over suggests that refugee inflows may contribute to mitigate the pace of local population ageing at least temporarily. Yet, in other rapidly ageing societies such as Germany, Spain and Portugal, Ukrainian refugees seemed more likely to locate in urban areas characterised by young population structures, and thus do not have an immediate impact on alliviating local issues of population ageing. At the same time, we found a consistent negative relationship between local levels of unemployment and population change in Czechia, Hungary, Poland, Slovakia, Germany and Italy suggesting that Ukrainian refugees have gravitated to areas with "healthy' ' labour markets. Such evidence is consistent with commentators anticipating that most Ukrainians are likely to stay in areas where vacant jobs are plentiful and available workers are relatively scarce (Hinshaw and Lovett 2022). Some may argue that increasing spatially focused levels of refugee migration could lead to a rise in local unemployment levels, but we argue that they could also result in job creation through greater demand for services and goods. We also showed that the relationship between

unemployment and population change is not linear and that high unemployment areas may be experiencing large intakes of Ukrainian refugees in Italy and Spain. Consistent with anecdotal evidence, our findings suggest that such situation may be occurring in rural areas in Italy with limited job opportunities (Zavialova 2022). Providing the necessary humanitarian assistance in these areas may be more challenging because of the lack of institutional structures for their delivery. Appropriate arrangements may need to be made.

Our analysis demonstrates the value of digital trace 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 2021). Access to data is restricted for ethical and privacy considerations. Yet, successul data sharing frameworks to grant access to data have started to proliferate. Meta's Data for Good initiative is a good example, reengineering data to ensure privacy, anonymisation and confidentiality before making them available. However, this approach may impose critical challenges. A key challenge is increased vulnerability to changes to institutional data sharing practices. For instance, the population data used in this paper to measure subnational population changes in European countries receiving Ukrainian migrants since the start of the invasion were discontinued in May. While an improved release of similar population data is planned, their discontinuation implies that we cannot apply the same approach to continue monitoring changes in population in Europe as the war unfolds, at least in the short term. A second challenge is we cannot directly measure population displacement due to the war in Ukraine and identify the origins and destinations of these movements. We approximated these movements analysing changes in local populations. While this is not a serious constrain, it resonates with calls made elsewhere to triangulate digital trace data with other sources of information as we have done in this paper (Rowe et al. 2021; Rowe et al. 2022) .

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