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Research Report

The demographic challenges to Ukraine's economic reconstruction

Policy Notes and Reports, No. 71

Provided in Cooperation with:

The Vienna Institute for International Economic Studies (wiiw) - Wiener Institut für Internationale Wirtschaftsvergleiche (wiiw)

Suggested Citation: Tverdostup, Maryna (2023) : The demographic challenges to Ukraine's economic reconstruction, Policy Notes and Reports, No. 71, The Vienna Institute for International Economic Studies (wiiw), Vienna

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The Demographic Challenges to Ukraine's Economic Reconstruction

Maryna Tverdostup



The Demographic Challenges to Ukraine's Economic Reconstruction

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This paper was prepared as part of a series of studies devoted to Ukraine's reconstruction and recovery, in collaboration with the Bertelsmann Stiftung. We gratefully acknowledge the valuable input and financial support provided by the Bertelsmann Stiftung for our work on Ukraine's reconstruction.

Abstract

Even before the war started, Ukrainian demographic prospects were almost uniquely negative, even in the context of CESEE. Ukrainian population declined steadily over last decade and the war has significantly worsened Ukraine's already negative demographic outlook, to the extent that a shortage of labour, particularly in certain parts of the country, is highly likely to be one of the main challenges of post-war reconstruction. Our findings show that, regardless of our assumptions regarding the duration of the war and further military escalation, Ukraine's population will not return to its pre-war level even in 2040, and the decline will be most pronounced in the working-age population. Although the population will rise somewhat in the years following the war, as soon as return migration flows run low, the population dynamic will turn negative again. Simulated population size ranges between 34.6m and 35m in 2040, which is around 20% below the 2021 level, with an improved fertility rate and declining mortality having very limited capacity to offset the rapid population decline. Our results suggest that over 20% of refugees will not return after the war, with many of those being working-age Ukrainians and their children, resulting in a long-lasting negative impact on Ukraine's population and reconstruction prospects.

Keywords: Ukraine, demographic trends, outward and return migration, post-war reconstruction

JEL classification: J11, J13, O15

CONTENTS

Abstract.....	5
1. How big were Ukraine’s demographic challenges before the war and why does this matter?.....	9
2. How has the war impacted the population?.....	14
2.1. What we can measure	14
2.2. What we can project	21
3. What are the policies that can best mitigate the decline?	25
3.1. Getting refugees to return	26
3.2. Encouraging new immigration.....	27
3.3. Increasing the birth-rate	28
3.4. Getting workers to the areas of the country where they will be most needed	30
Technical Appendix.....	32

TABLES AND FIGURES

Table 1 / Simulated population size across six scenarios – maximum total and working-age population size achieved over years 2022-2040 and population size in 2040	22
Figure 1 / Total population by gender and countries in 1990-2021	9
Figure 2 / Fertility and average childbearing age by countries in 1990-2021	10
Figure 3 / Life expectancy at birth by gender and countries in 1990-2021	11
Figure 4 / Net migration rate by countries in 1990-2021	11
Figure 5 / Ukrainian population by age and gender in years 1990, 2005 and 2021	12
Figure 6 / Employment by age and gender in Ukraine, 2017 and 2021	12
Figure 7 / Educational attainments in Ukraine	13
Figure 8 / Distribution of Ukrainian population by regions as of 1 February 2022	15
Figure 9 / Daily dynamic in number of internally displaced (IDP), refugees, civilian injuries and deaths since the start of the war until 2 March 2023	15
Figure 10 / Estimated numbers of internally displaced persons (IDP) in Ukraine in 2022 (millions)	16
Figure 11 / Estimated numbers of internally displaced persons (IDP) in Ukraine across macro regions by origin and destination in 2022 (thousands)	17
Figure 12 / Estimated reallocation intentions across time and by regions, %	18
Figure 13 / Dynamics and distribution of the refugee flow	19
Figure 14 / Simulated population projections under six macro scenarios for years 2022-2040	23
Figure 15 / Simulated population by gender under six macro scenarios for years 2022-2040, thousand	25

Appendix

Table A.1 / Upper and lower limits of uniform distribution used for simulation of refugee outflow across gender-age cohorts and across six macro scenarios	41
Table A.2 / Upper and lower limits of uniform distribution used for simulation of returnee inflow across gender-age cohorts and across six macro scenarios	42

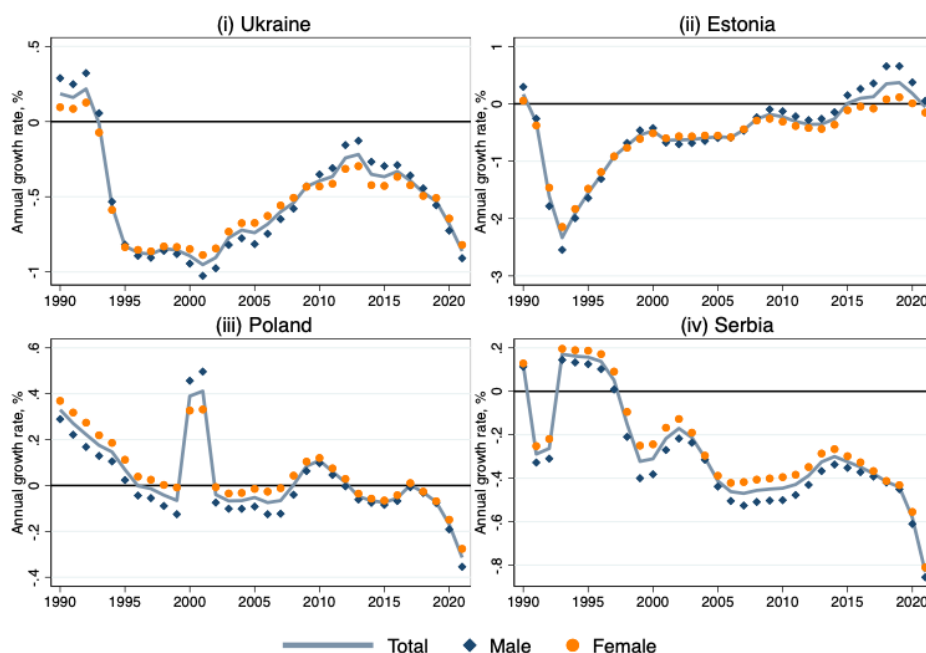
The demographic challenges to Ukraine's economic reconstruction

1. HOW BIG WERE UKRAINE'S DEMOGRAPHIC CHALLENGES BEFORE THE WAR AND WHY DOES THIS MATTER?

Even when compared with other CESEE countries,¹ most of which are also facing major demographic challenges, Ukraine's pre-war demographic prospects were particularly negative.

This was already straining the labour market, holding back the development of promising areas of the economy and capping overall growth potential. During the past three decades, Ukraine's population fell by almost 20%, substantially more than in comparator countries – in Estonia, the population dropped by around 15.5% between 1990 and 2021; in Poland, total population in 2021 was at the 1990 level, and in Serbia it declined by 8.7% over the respective time period (Figure 1).

Figure 1 / Total population by gender and country, 1990-2021



Note: Mid-year population (as of 1 July). Population growth rate is computed as the difference between the population in the current year and in the previous year, divided by the population in the previous year, and multiplied by 100. A noticeable spike in the population growth rate in Poland around the year 2000 relates to the population census conducted in that year.

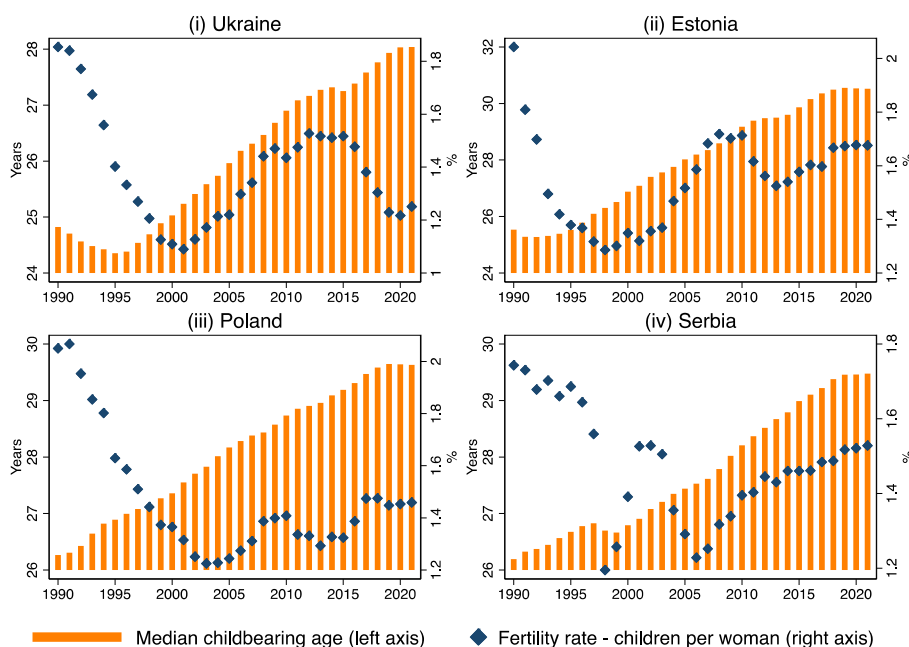
Source: United Nations population statistics, POP/DB/WPP/Rev.2022/GEN/F01/Rev.1

¹ In this section, we compare Ukraine with Estonia, Poland and Serbia. Estonia is another post-Soviet state that faced a similar demographic downturn after the breakdown of the Soviet Union, but exhibited very different developments in the latter two decades. Poland, although not a part of the Soviet Union, had comparable post-WWII demographic developments to Ukraine, as well as similar early-1990s migration outflow following the dissolution of the Eastern Bloc. The choice of Serbia is rationalised by the tremendous demographic shock caused by the Yugoslav war, especially in the early 1990s, which is largely comparable to the population decline faced now by Ukraine.

There are five key reasons for Ukraine's particularly negative pre-war demographic trends even within the CESEE context, and all of these are relevant for post-war reconstruction planning:

- › First, despite women on average giving birth at a younger age than in peer countries, Ukraine has a particularly low birth rate by CESEE standards (Figure 2).
- › Second, Ukraine had a particularly low level of life expectancy by CESEE standards, even before the war (Figure 3), related above all to health issues, especially among men.²
- › Third, Ukraine has experienced higher net outward migration over the past three decades than its CESEE peers (Figure 4), and this has intensified sharply since the first Russian invasion of 2014. (Poland's net migration, meanwhile, would have been much more negative without the influx of Ukrainians, around 2m of whom were working in the Polish labour market before the war.)³
- › Fourth, the Ukrainian population has undergone drastic ageing over the past three decades, and hence the decline in the working-age population (the key for reconstruction) has been even bigger than that of the population as a whole (Figure 5). The share of those aged 65 and above in the total population increased from 12% in 1990 to almost 18% in 2021, whereas the share of those aged under 14 (an indicator of the future workforce) dropped from 21% in 1990 to 15% in 2021.
- › Fifth, the employment rate has fallen substantially since 2017, meaning that Ukraine is not even fully utilising the dwindling labour resources at its disposal (Figure 6) and that the labour market has still not recovered from the impact of the COVID-19 pandemic.

Figure 2 / Fertility and average childbearing age by country, 1990-2021

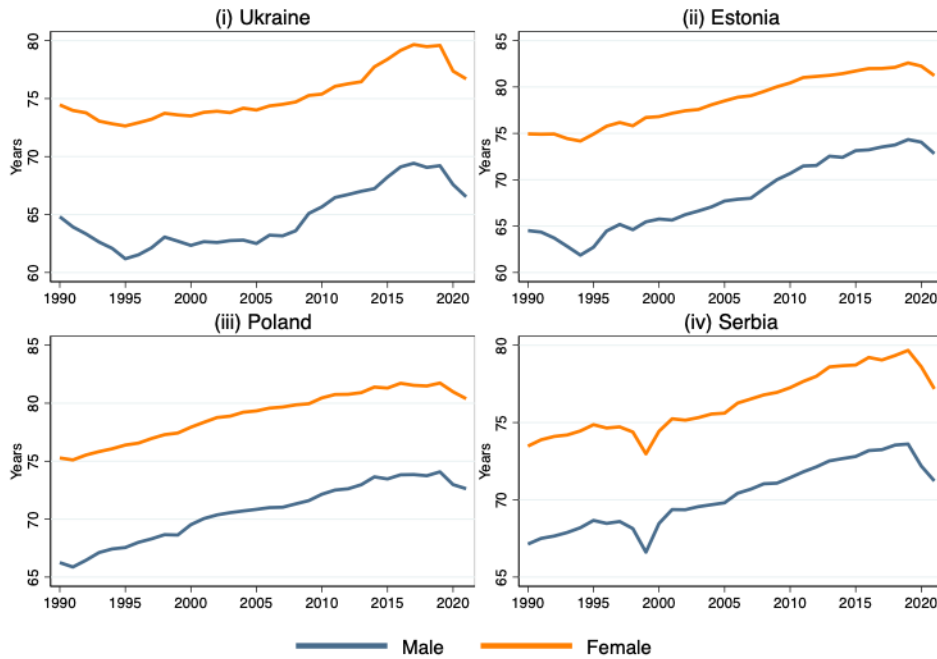


Source: United Nations population statistics, POP/DB/WPP/Rev.2022/GEN/F01/Rev.1

² Including cardiovascular diseases and health problems caused by tobacco and alcohol use. <https://vo.ukraine.org/en/life-expectancy-in-ukraine-why-is-it-so-low/>

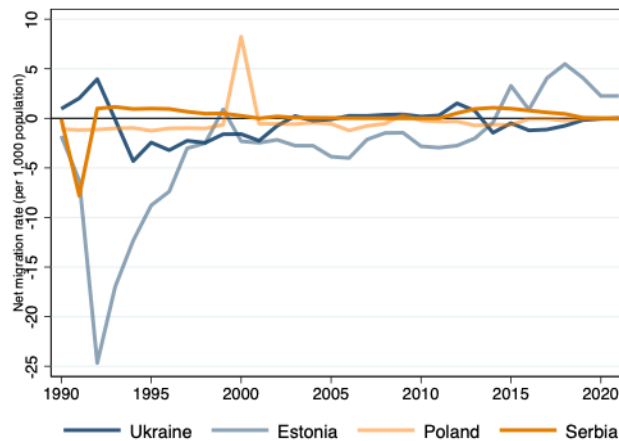
³ Brunarska, Z., M. Kindler, M. Szulecka and S. Toruńczyk-Ruiz (2016), 'Ukrainian migration to Poland: a "local" mobility?', in: O. Fedyuk and M. Kindler (eds), *Ukrainian Migration to the European Union: Lessons from Migration Studies*, Springer, pp. 115-131.

Figure 3 / Life expectancy at birth by gender and country, 1990-2021



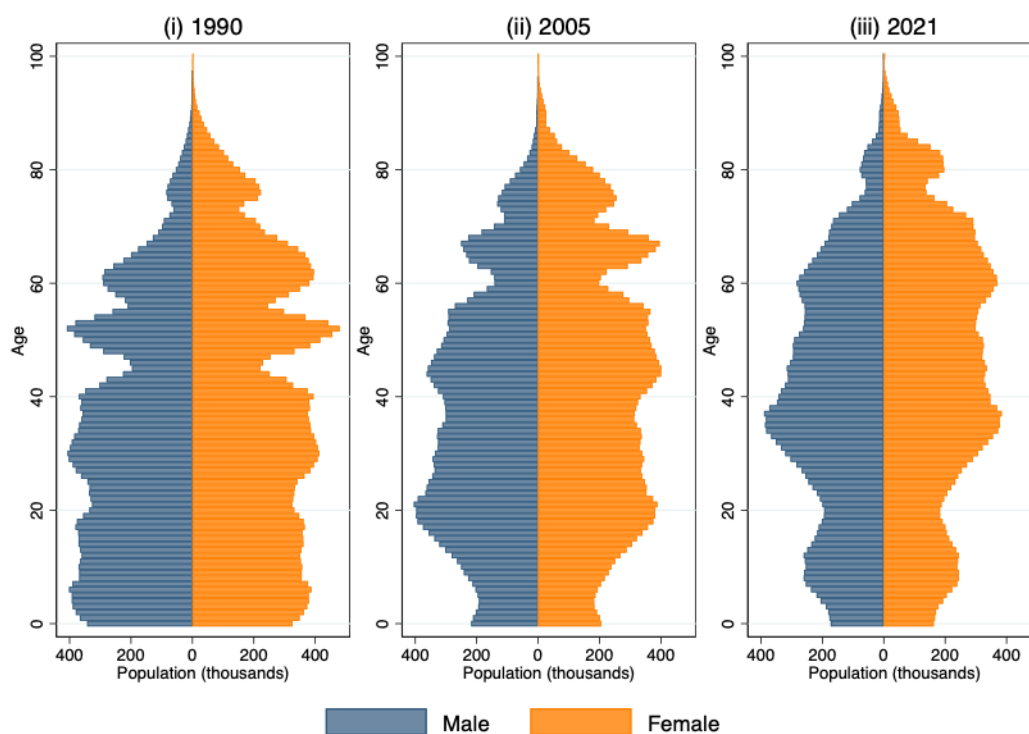
Source: United Nations population statistics, POP/DB/WPP/Rev.2022/GEN/F01/Rev.1

Figure 4 / Net migration rate by country, 1990-2021



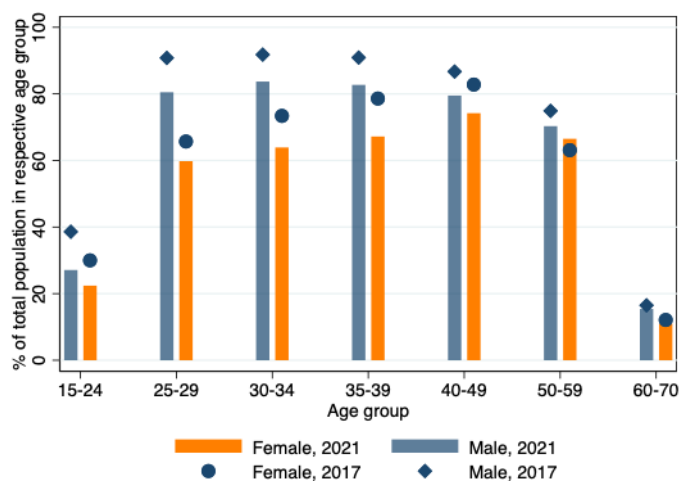
Note: Net migration rate computes as the number of immigrants minus the number of emigrants over a period, divided by the person-years lived by the population of the receiving country over that period. It is expressed as net number of migrants per 1,000 population.

Source: United Nations population statistics, POP/DB/WPP/Rev.2022/GEN/F01/Rev.1

Figure 5 / Ukrainian population by age and gender, 1990, 2005 and 2021

Note: Mid-year population (as of 1 July).

Source: United Nations population statistics, POP/DB/WPP/Rev.2022/GEN/F01/Rev.1

Figure 6 / Employment by age and gender in Ukraine, 2017 and 2021

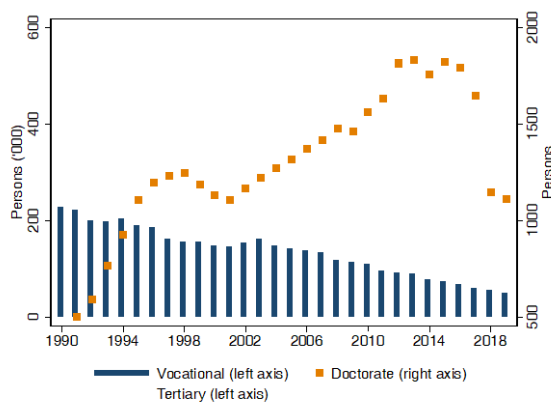
Source: State Statistics Service of Ukraine (<https://ukrstat.gov.ua>).

Although Ukraine's demographic trends are negative, the quality of labour has been improving, and this could help with reconstruction efforts, as long as people stay or return quickly after the war ends. Although Ukraine will continue to face a shortage of workers in many sectors and regions, the quality of the workers that it does have is quite high by CESEE standards.

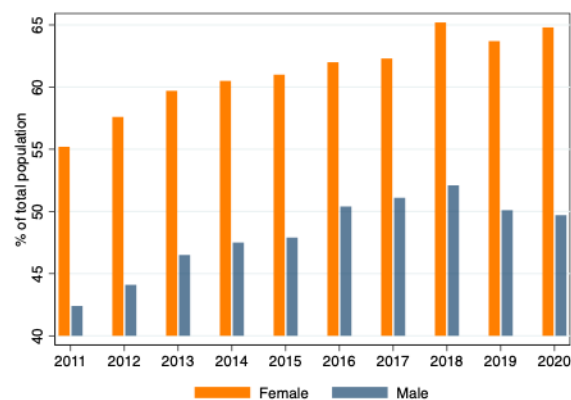
The key positive factor in relation to labour quality is that Ukrainians are highly educated (Figure 7). The number of people with tertiary education increased threefold in 1990-2010 and, given the overall population decline over the same time frame, the share of the population with tertiary education will have increased by even more during this period. Average educational attainments in Ukraine are much higher than the EU27 average for both men and women,⁴ although this must be considered in the context of notable differences in educational systems, as well as availability of higher education institutions and job-related formal education requirements.⁵

Figure 7 / Educational attainments in Ukraine

(i) Number of graduates by education level in Ukraine, 1990-2019



(ii) % of total population with tertiary education by gender among those aged 30-34 in Ukraine, 2011-2020



Note: The estimates from 2014 onwards exclude the temporarily occupied territory of the Autonomous Republic of Crimea, the city of Sevastopol and a part of the temporarily occupied territories in the Donetsk and Luhansk regions.

Source: State Statistics Service of Ukraine (<https://ukrstat.gov.ua>).

Ukrainian women are much better educated than men, which is highly relevant for reconstruction, given that women have left in much higher numbers (see below for a full discussion of this). The share of women with tertiary education has increased by 10 percentage points (pp) over the past decade – from 55% to 65%. Meanwhile, the share of men with tertiary education, despite a notable improvement (from 42% to 50%) remains well below the female level.

However, despite the higher qualifications of women, they remain less likely to be employed than men, which will be a barrier to reconstruction efforts if not addressed. The largest disparities between male and female employment rates are for those aged from 25 to 39, i.e. much of the core of the working-age population. The most striking gap of 20 pp in 2017 and 23 pp in 2021 was recorded in age groups 25 to 29, which suggests a significant labour market penalty for childbirth (the median

⁴ In 2021 the EU27 average share of those aged 25-34 with tertiary education was around 35% for men and around 47% for women; this is significantly below the formal educational attainments in Ukraine in the same year.

https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Educational_attainment_statistics#Educational_attainment_levels_vary_between_age_groups

⁵ Higher education opportunities are, generally, very broad and offer both state-funded and private-funded places, depending on the type of educational institution (private or public) and the level of academic achievements of applicants. Formal education requirements are very high in the Ukrainian labour market, as a majority of even medium-level occupations require higher education.

childbearing age falls within this age range). Nevertheless, the gender gap in employment persists throughout the lifecycle, although it declines notably with age. In the context of almost certain post-war labour shortages, Ukrainian policy makers can no longer afford to leave this issue unaddressed. Even if female refugees return after the war, Ukraine will have to get much better at integrating them into the labour market in order to fully utilise their skills in the reconstruction efforts.

The overall demographic picture for Ukraine pre-February 2022 was clearly already negative. Ukraine has experienced a more significant decline in its population over the past 30 years than its CESEE peers. Moreover, it compares unfavourably with its regional peers over the last decade in terms of birth rates, life expectancy, net migration and the age of its population. The reasons for these problems are multiple and complex, but clearly are linked to the unresolved situation in the east of Ukraine, low income levels, a high share of people at risk of poverty, the social insecurity of the population and an ineffective healthcare system.⁶ Although the population is relatively highly educated, this applies above all to women, who were badly integrated into the labour market pre-war and have left in much higher numbers than men since February 2022. In the context of reconstruction, much of which will be extremely labour-intensive, as outlined above, and given the further drastic negative demographic shock of the war, which we will explore below, this challenging demographic outlook is now even more problematic.

2. HOW HAS THE WAR IMPACTED THE POPULATION?

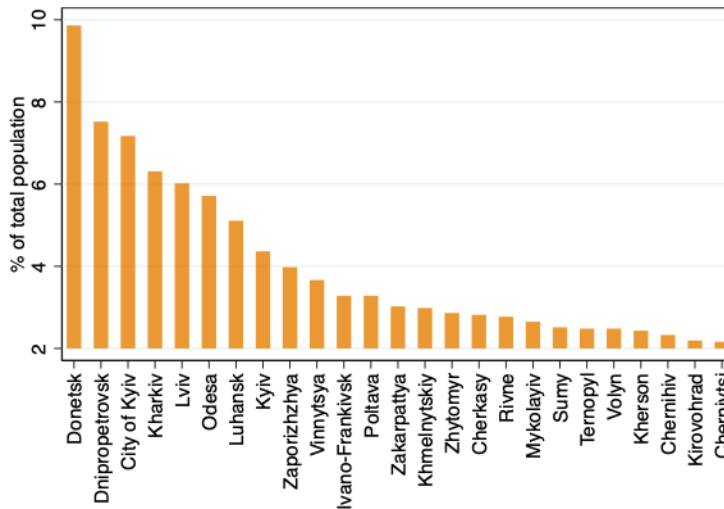
2.1. What we can measure

We can already measure the initial impact of the war on the population, both at the macro level, but also in terms of what it means in terms of skills, age and regional composition, all of which are relevant for reconstruction. The war is likely to cause an irreversible demographic shock, which will result in a sizeable long-term decline in the population, much larger than was projected before the war. The regions of Ukraine that are most heavily affected by the war – Donetsk, Kharkiv, Luhansk, Zaporizhzhya, Mykolayiv and Kherson – jointly accounted for over 30% of the Ukrainian population before the 2022 invasion (Figure 8).

From the first days of the war, it became evident that its footprint on the demographic situation would be dramatic. Figure 9 provides a summary of the main demographic implications of the war – internal displacement, refugee outflow, civilian injuries and deaths. Cumulative numbers of internally displaced persons (IDPs) and refugees rose sharply in the first three months of the war, with those for IDPs reaching their maximum in early June 2022 and refugees in mid-August 2022. An improvement in the frontline situation over the summer resulted in a marginal decline in those internally and externally displaced, but one year after the start of the war, the numbers fluctuated around 5.5m for IDPs and 8m for refugees. By March 2023 the number of civilian injuries had reached almost 14,000 and the number of (confirmed) civilian deaths exceeded 8,000. The following sub-sections will discuss these key demographic implications of the war in detail.

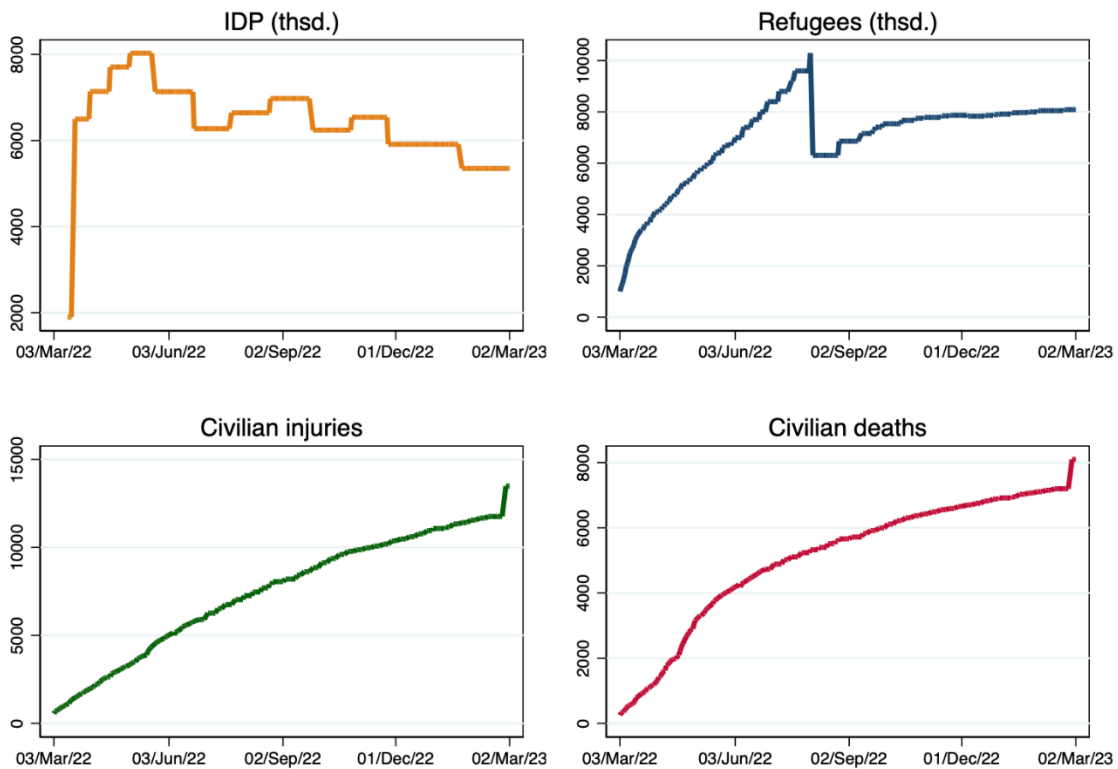
⁶ https://population.un.org/wpp/publications/files/wpp2019_highlights.pdf

Figure 8 / Distribution of Ukrainian population by regions, 1 February 2022



Note: The estimates exclude the temporarily occupied territory of the Autonomous Republic of Crimea, the city of Sevastopol and a part of temporarily occupied territories in the Donetsk and Luhansk regions.
 Source: State Statistics Service of Ukraine (<https://ukrstat.gov.ua>).

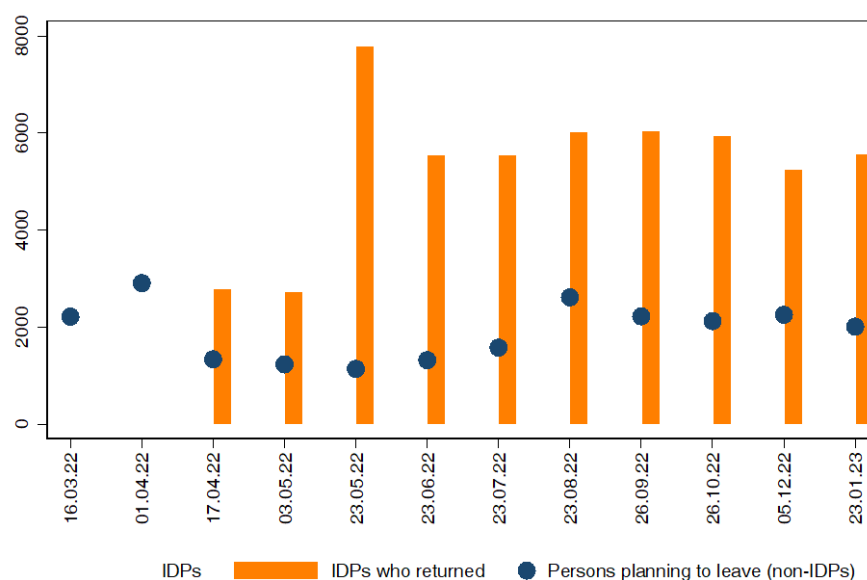
Figure 9 / Daily dynamic in number of internally displaced persons (IDPs), refugees, civilian injuries and deaths since the start of the war until 2 March 2023



Source: UNHCR, The Humanitarian Data Exchange (<https://microdata.unhcr.org/index.php/catalog/HDX/?page=1>).

As of 4 February 2023, there were 7,110 confirmed fatalities among the civilian population and 11,547 injuries.⁷ According to recent evidence from senior Ukrainian officials, the number of soldiers killed had exceeded 13,000 by December 2022.⁸ However, estimates by US military chiefs suggest up to 100,000 killed and wounded soldiers, as of November 2022.⁹ ¹⁰ These numbers should be taken with extreme caution. As of the beginning of 2023, around 18% of Ukrainian territory is occupied by Russian forces. Therefore, the real scale of fatalities may be drastically higher than existing estimates, as almost no statistical evidence is available on fatalities in the occupied territories of Donetsk and Luhansk regions. According to various investigations, in Mariupol alone the number of killed civilians could be around 90,000.¹¹ It will probably never be possible to estimate with any certainty an accurate number of fatalities in the territories occupied by Russia, as Russian military forces attempt to cover up the terrifying scale of death and destruction.^{12,13} It is also clear that mortality, especially among the civilian population, is not caused only by direct military action, but may also arise from indirect effects of the war, such as lack of food and medication, limited or no access to medical services, extreme stress and the increased incidence of serious health problems in light of all the aforementioned factors.

Figure 10 / Estimated numbers of internally displaced persons (IDPs) in Ukraine, 2022 ('000)



Note: All population estimate figures are rounded to the nearest thousand.

Source: International Organization for Migration (IOM) Mission in Ukraine, Internal Displacement Survey, round 11 (<https://displacement.iom.int/reports/ukraina-zvit-pro-vnutrishne-peremischennya-v-ukraini-opituvannya-zagalnogo-naselennya-raund>).

⁷ <https://wiiw.ac.at/ukraine-c-101.html>

⁸ <https://www.bbc.com/news/world-europe-63829973>

⁹ <https://www.bbc.com/news/world-europe-63580372>

¹⁰ A precise assessment of war casualties is impossible. The Ukrainian government does not disclose the actual figures of deceased military personnel, and existing fragmentary estimates vary significantly.

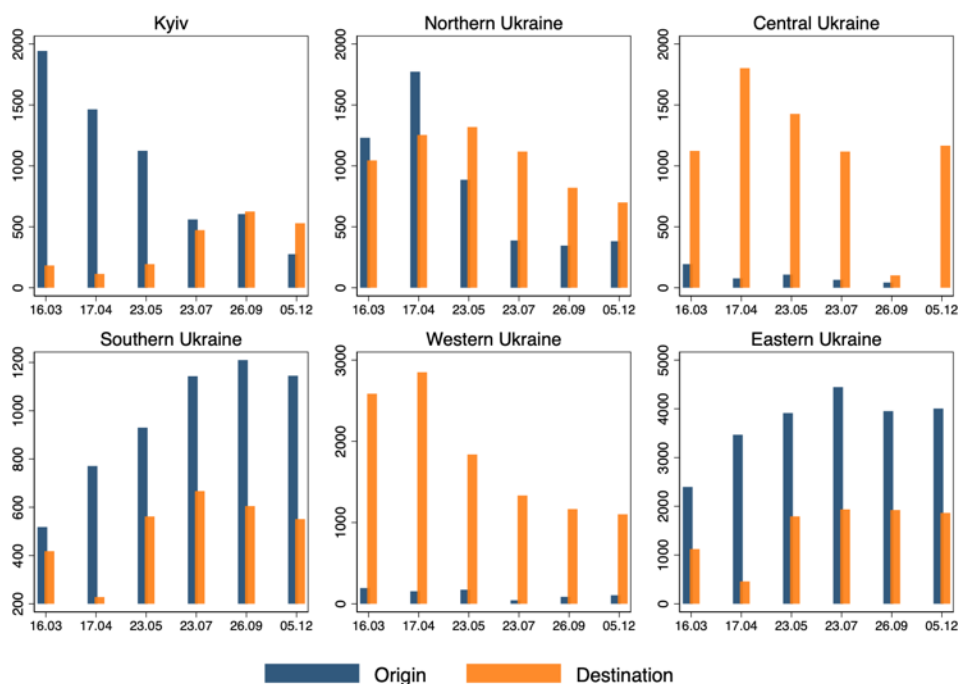
¹¹ <https://bykvu.com/eng/bukvy/87-000-documented-deaths-in-mariupol-media-report/>

¹² <https://www.ohchr.org/en/press-releases/2022/12/un-report-details-summary-executions-civilians-russian-troops-northern>

¹³ <https://apnews.com/article/russia-ukraine-kyiv-europe-middle-east-government-and-politics-e3756976cf33cf5de29aa62d61ea7eb6>

According to the International Organization for Migration, displacement of the population within Ukraine stood at around 5.9m as of 5 December 2022.¹⁴ Soon after the start of the Russian invasion around 6.5m people became internally displaced (as of 16 March 2022) and the estimate rose to around 8m by the beginning of May, before a decline to 7.1m by the end of that month (Figure 10). Notably, return mobility had begun in April, and by the end of May the estimated number of IDPs who had returned exceeded the estimate of the currently displaced population. The evolution of military actions, especially the liberalisation in May of the Kyiv region and the Northern macro region of Ukraine, fuelled return mobility, as many people headed back home as soon as Russian military forces left. However, from June 2022 onwards the estimate of currently displaced population exceeded the number of IDPs who returned.

Figure 11 / Estimated numbers of internally displaced persons (IDPs) in Ukraine across macro regions by origin and destination, 2022 ('000)



Note: All population estimates are rounded to the nearest thousand. A macro region is a territorial unit that includes oblasts (regions), as defined in the Law of Ukraine 'On the Basics of State Regional Policy' (Part 2 of Article 1). Macro regions are defined as follows: Northern Ukraine – Zhytomyr, Kyiv region, Chernihiv, Sumy; Central Ukraine – Vinnytsya, Dnipropetrovsk, Kirovohrad, Poltava, Cherkasy; Southern Ukraine – Zaporizhzhya, Mykolayiv, Odesa, Kherson; Western Ukraine – Zakarpattia, Lviv, Volyn, Ivano-Frankivsk, Rivne, Ternopol, Chernivtsi, Khmelnytskyi; Eastern Ukraine – Kharkiv, Donetsk, Luhansk.

Source: International Organization for Migration (IOM) Mission in Ukraine, Internal Displacement Survey, round 11 (<https://displacement.iom.int/reports/ukraina-zvit-pro-vnutrishne-peremischennya-v-ukraini-opituvannya-zagalnogo-naselennya-raund>).

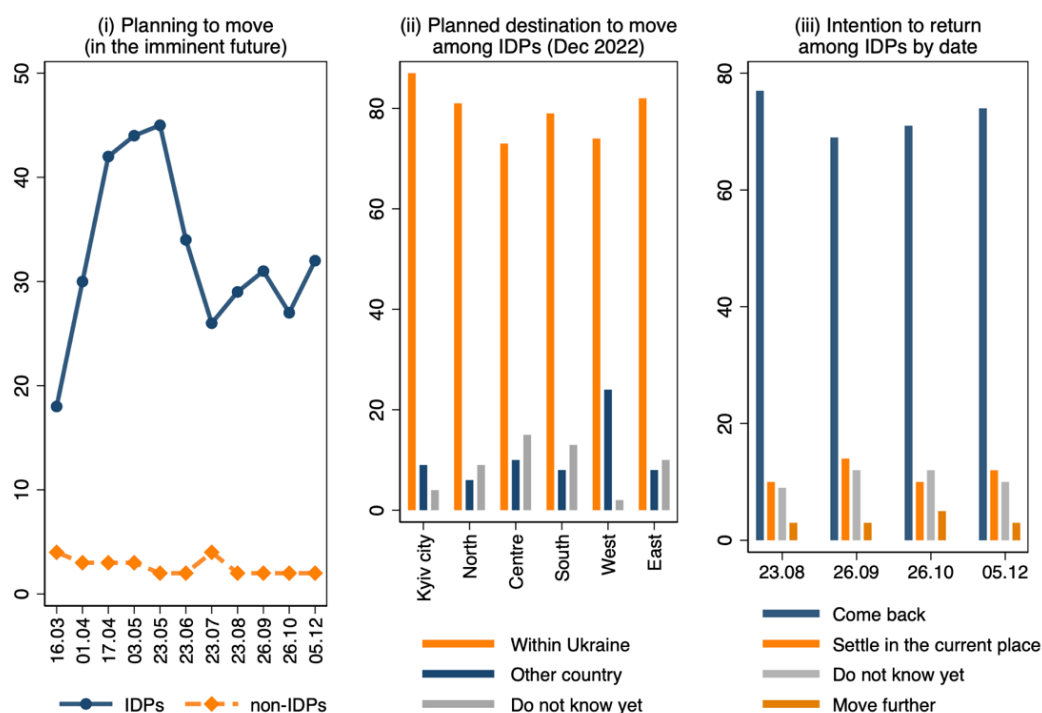
Data show that the movements of IDPs within Ukraine are heavily affected by where the fighting is taking place, and that the population reacts quickly once an area is liberated from Russian control (Figure 11). In the early months of the war, the dominant share of IDPs originated from the city of Kyiv, and Northern and Eastern Ukraine – the regions facing the most devastating military actions

¹⁴ <https://displacement.iom.int/reports/ukraina-zvit-pro-vnutrishne-peremischennya-v-ukraini-opituvannya-zagalnogo-naselennya-raund>

from the first day of the invasion. However, a steadily high estimate of IDPs whose destination was the Northern macro region of Ukraine suggests that many of those who were internally displaced remained within the same macro region, moving further from the front line but intending to return as soon as the situation allows.

From the end of May 2022 onwards, the majority of IDPs originated from the Southern and Eastern macro regions of Ukraine, as the front line stretched across the regions of Donetsk, Luhansk, Kharkiv, Zaporizhzhya, Mykolayiv and Kherson. Furthermore, a mandatory evacuation of residents from Donetsk region in August increased outward mobility from the East.¹⁵ As the gap between the numbers of IDPs originating and settling in the Southern and Eastern macro regions of Ukraine is steadily high, the severe depopulation of these two regions is self-evident. However, the opposite holds for the Central and Western macro regions of Ukraine and for the Northern macro region from May 2022 onwards, suggesting less severe depopulation of these regions, owing to an inflow of internally displaced Ukrainians.

Figure 12 / Estimated reallocation intentions across time and by region, %



Note: A macro region is a territorial unit that includes oblasts (regions), as defined in the Law of Ukraine 'On the Basics of State Regional Policy' (Part 2 of Article 1). Macro regions are defined as follows: Northern Ukraine – Zhytomyr, Kyiv region, Chernihiv, Sumy; Central Ukraine – Vinnytsya, Dnipropetrovsk, Kirovohrad, Poltava, Cherkasy; Southern Ukraine – Zaporizhzhya, Mykolayiv, Odesa, Kherson; Western Ukraine – Zakarpattya, Lviv, Volyn, Ivano-Frankivsk, Rivne, Ternopol, Chernivtsi, Khmelnytskyi; Eastern Ukraine – Kharkiv, Donetsk, Luhansk.

Source: International Organization for Migration (IOM) Mission in Ukraine, Internal Displacement Survey, round 11 (<https://displacement.iom.int/reports/ukraine-zvit-pro-vnutrishne-peremischennya-v-ukraini-opituvannya-zagalnogo-naseleennya-raund>).

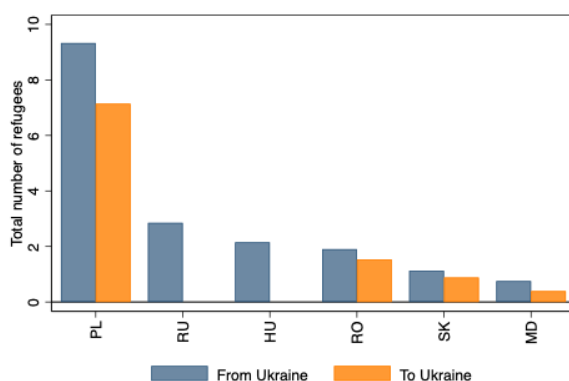
¹⁵ https://lb.ua/society/2022/08/10/525800_z_donechchini_vid_pochatku_obovyazkivoi.html

As a result of the massive internal displacement of people from regions that are temporarily occupied or in which active hostilities are ongoing, the demographic composition of some regions of Ukraine – primarily Eastern and Southern – has changed. This has greatly affected the quantitative, age and gender structure of their population, as a large proportion of women (of all age groups), children and teenagers have left their permanent residences. Evidence suggests that the share of women among IDPs has increased steadily over time (from 54% in March to 70% in August 2022),¹⁶ which could be a consequence of increased military conscription, as well as economic reasons, such as lack of employment possibilities in the host region. By the end of 2022, around 26% of IDPs were aged under 17 and 21% were aged over 60.¹⁷ This will have important implications for post-war reconstruction, as it could point to a long-lasting shift in population distribution within Ukraine, with some regions benefiting and others losing out. However, at least for now, the majority of IDPs want to return home, and relatively few want to leave Ukraine (Figure 12), although this could well change depending on how the war unfolds. The challenge of getting people to return to areas affected by the war will be a key element of post-war policy and an important determinant of the success of reconstruction.

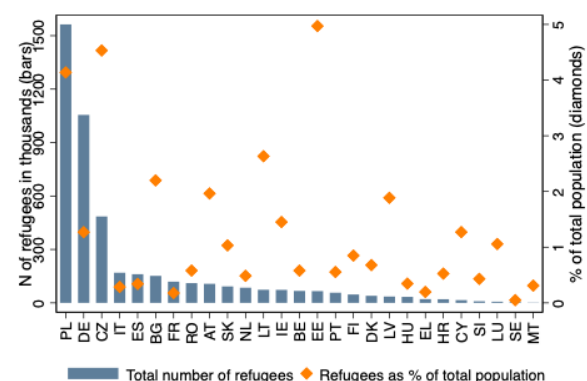
So far, the net outflow of refugees from Ukraine stands at around 8m. Altogether, more than 18m border crossings from Ukraine were recorded from the beginning of the Russian invasion until the start of January 2023.¹⁸ However, by the beginning of October 2022, almost 10m border crossings to Ukraine were recorded, many by Ukrainians coming back permanently (including a large number of returning refugees, especially in the recent months) or for a short visit, with a subsequent return abroad. Of the more than 8m Ukrainians recorded in the EU, 4.8m were registered under the temporary protection or similar schemes as refugees (Figure 13).

Figure 13 / Dynamics and distribution of the refugee flow

(a) Number of Ukrainians who crossed the border to and from neighbouring states as of January 2023 (million)



(b) Number of Ukrainian refugees registered under temporary protection or similar schemes in EU countries as of January 2023



Note: Data on border crossings from Hungary and Russia to Ukraine are missing.

Source: <https://data.unhcr.org/en/situations/ukraine>

¹⁶ https://euaa.europa.eu/sites/default/files/publications/2022-11/2022_11_09_Forced_Displacement_Ukraine_Joint_Report_EUAA_IOM_OECD_0.pdf

¹⁷ <https://displacement.iom.int/reports/ukraina-zvit-pro-vnutrishnye-peremischennya-v-ukraini-opituvannya-zagalnogo-naselennya-raund>

¹⁸ Total estimates of the number of border crossings and refugees are available at <https://data.unhcr.org/en/situations/ukraine>

The character of the refugee outflow risks further exacerbating Ukraine's demographic challenges. Over one-third of refugees are children, and of the adults at least 70% are female.^{19,20,21,22} Hence the outflow is very different from the normal pre-war outward migration in terms of age and gender composition. This will have a long-lasting impact on the demographic situation in Ukraine, not only as a consequence of outward mobility per se, but also because of a major decline in the number of births, as a majority of refugees are women of child-bearing age.

Ukraine also seems to be losing a disproportionate number of its better-educated citizens.

Evidence on exact educational attainments of Ukrainian refugees is still rather limited, but available data suggest a significantly higher share of highly educated (university degree or equivalent) refugees among Ukrainians, compared with refugees from the earlier wave of 2014-2016. The results of the aforementioned UNHCR regional monitoring suggest that 47% of Ukrainian refugees hold a university degree and that 29% of refugees have vocational education.²³

As the war continues and the damage to infrastructure continues to mount, the likelihood of Ukrainian refugees staying permanently abroad increases, which would be disastrous for reconstruction. Even though an increasing number of refugees are coming back, many of these are those whose property has not been damaged or are from the regions less affected by the war. Even if the Ukrainian army manages to liberate more territories this year and beyond, these conducive conditions for refugees to return are much less likely to be the case in future.

A survey conducted in August-September 2022 in 43 countries²⁴ suggests that 81% of all refugees intend to return home at some point in the future, but only 13% planned to do so within the next three months. This underlines that as long as the war continues, relatively few will return. The results of UNHCR regional monitoring indicate that 63% of respondents intend to stay in a host country for the time being and only 14% plan to return to Ukraine within the next few months, with 86% of all surveyed refugees having concerns about a return to Ukraine in the foreseeable future. Predominant

¹⁹ https://data.unhcr.org/en/documents/details/95767#_ga=2.5544499.1218543842.1663938030-518881478.1646318875

²⁰ <https://blogs.lse.ac.uk/europpblog/2022/09/07/what-the-self-selection-of-ukrainian-refugees-means-for-support-in-host-countries/>

²¹ <https://reliefweb.int/report/poland/refugees-ukraine-poland-profiling-update-june-2022>

²² <https://www.oecd.org/ukraine-hub/policy-responses/what-we-know-about-the-skills-and-early-labour-market-outcomes-of-refugees-from-ukraine-c7e694aa/>

²³ The studies from Germany report that the share of tertiary-educated refugees exceeds 73% (<https://www.cesifo.org/en/publications/2022/article-journal/prospects-integration-ukrainian-refugees-german-labor-market>).

Spanish administrative data suggests that 62% of Ukrainian refugees hold university degrees. (https://www.oecd-ilibrary.org/social-issues-migration-health/international-migration-outlook-2022_30fe16d2-en?utm_medium=email&utm_source=berlin-newsletter&utm_content=en&utm_term=berl&utm_campaign=berlin-international-migration-outlook-2022), while a cross-country survey of 43 EU and non-EU countries reports a share of 70% (<https://data.unhcr.org/en/documents/details/95767>).

In Austria, the share of tertiary-educated refugees ranges as high as 83% (<https://blogs.lse.ac.uk/europpblog/2022/09/07/what-the-self-selection-of-ukrainian-refugees-means-for-support-in-host-countries/>).

The high educational profile of Ukrainian refugees is explained by formal education levels of Ukrainians ranging above the EU27 average, as well as by the positive self-selection, as Ukrainian refugees registered in Europe are, on average, more educated than the overall Ukrainian population. (<https://blogs.lse.ac.uk/europpblog/2022/09/07/what-the-self-selection-of-ukrainian-refugees-means-for-support-in-host-countries/>).

²⁴ <https://data.unhcr.org/en/documents/details/95767>

among these concerns were likely to be issues surrounding safety, employment and access to basic social services, including health care. Thus, although return intentions are fluctuating in response to the dynamics of the war, as well as access to basic services and living conditions in the host countries, millions of Ukrainians are likely to stay in other countries in Europe for an indefinite period.

2.2. What we can project

Despite the huge uncertainty, having some idea of the potential scenarios for Ukraine's demographic future is crucial to prepare a workable reconstruction plan. This means understanding, under a range of scenarios, the number of people that Ukraine will have lost permanently (or at least for many years) as a result of the invasion, and also their demographic profile (age, gender etc.).

There are few current demographic projections for Ukraine, probably because of the huge uncertainty about the future course of the war. The Ptoukha Institute for Demography and Social Studies of the National Academy of Sciences of Ukraine expects the population to decline to 35m by 2030, owing to high mortality, a very low birth rate, and outward migration;²⁵ the population at the beginning of 2023 had already declined to 36.7m.²⁶ The UN projects that Ukraine's population will never recover from the war, and that by 2050 it will be at least 20% smaller than at present.²⁷ Another study projects a 16% population decline over the next two decades, based on current trends.²⁸

However, so far there has been no complete population projection model for Ukraine with population ageing accounted for. We fill this gap, projecting future demographic developments with several simultaneous stochastic processes, representing the evolution of age-specific fertility, age- and gender-specific mortality, age- and gender-specific refugee outflow rate, and age- and gender-specific return rates, with the behaviour of these stochastic processes being determined by the imposed macro scenarios, i.e. assumptions on duration of the war and further military escalation. Hence, our simulation results are both scientifically novel and crucial for formulating sound policy recommendations.²⁹

Our results show that under any feasible scenario, Ukraine is going to suffer a long-term population loss as a result of the conflict. However, the range of outcomes in our different scenarios is very wide, meaning that the future path of the war and how long it lasts will be extremely important in determining how big the demographic shock will be, and how much this will impact the reconstruction process. Table 1 provides an overview of simulated population size across six scenarios by focusing on the maximum population size reached in the post-war years and the total population at the end of the simulation horizon, in 2040.

²⁵ According to the estimates of the Ptoukha Institute for Demography and Social Studies of the National Academy of Sciences of Ukraine. <https://www.ukrinform.ua/rubric-society/3641463-demografi-prognozuut-so-u-2023-roci-na-ukrainu-cekae-katastroficne-padinna-narodzuvanosti.html>

²⁶ <https://worldpopulationreview.com/countries/ukraine-population>

²⁷ https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/wpp2022_summary_of_results.pdf

²⁸ <https://population-europe.eu/research/books-and-reports/war-and-future-ukraines-population>. The study employs a ready-made POPGROUP projection software (Edge Analytics 2020) and the results suggest a steady population decline, with its magnitude strongly dependent on the number of refugees who return.

²⁹ The detailed description of the demographic model used in our simulation exercise, as well as the simulation procedure and sequence, is provided in the Technical Appendix, which complements this chapter.

Table 1 / Simulated population size across six scenarios – maximum total and working-age population size achieved in 2022-2040 and population size in 2040

Scenario	Maximum population size achieved			Population in 2040	
	Year	Population, '000	Growth rate vs 2021, %	Population, '000	Growth rate vs 2021, %
I. Total population					
(i) 2023 and no escalation	2030	37,751.01	-13.3	36,029.06	-17.2
(ii) 2024 and no escalation	2031	37,035.51	-14.9	35,702.05	-18.0
(iii) 2025 and no escalation	2033	36,284.93	-16.7	35,322.95	-18.9
(iv) 2023 and escalation	2031	37,199.73	-14.6	35,774.00	-17.8
(v) 2024 and escalation	2033	36,125.09	-17.0	35,210.64	-19.1
(vi) 2025 and escalation	2035	35,163.17	-19.2	34,623.57	-20.5
II. Working-age population (18-60 years)					
(i) 2023 and no escalation	2030	21,804.37	-14.9	19,850.77	-22.6
(ii) 2024 and no escalation	2031	21,440.26	-16.4	19,666.66	-23.3
(iii) 2025 and no escalation	2032	21,053.51	-17.9	19,479.78	-24.0
(iv) 2023 and escalation	2031	21,593.73	-15.8	19,739.92	-23.0
(v) 2024 and escalation	2032	21,045.21	-17.9	19,463.31	-24.1
(vi) 2025 and escalation	2033	20,489.06	-20.1	19,180.63	-25.2

Note: Population in each year is estimated as an average of 10,000 MC simulation rounds.

The best-case scenario is that the war ends this year, and that between now and then there is no escalation of the conflict³⁰ (Table 1 and Figure 14). Even so, the cumulative number of refugees fleeing Ukraine will be 8.3m by the end of 2023. Under this scenario, Ukraine's population would start to increase again by 2024, and in 2030 will reach its post-war maximum of 37.8m,³¹ but the population will never return to pre-war (i.e. 2021) levels and in 2040 will be around 36m, some 17% lower than before the war. The working-age population (those aged 18 to 60) will shrink to 19.9m, or by 22.6% compared with 2021. Births would recover more quickly, fewer people would die, and refugees would return earlier than in the other scenarios. If the war ends this year but there is an escalation before it ends, the population will fall to 34.2m this year (a 21% drop relative to 2021), meaning that an escalation will see Ukraine lose a further 1.7m people even if the war ends fairly soon.

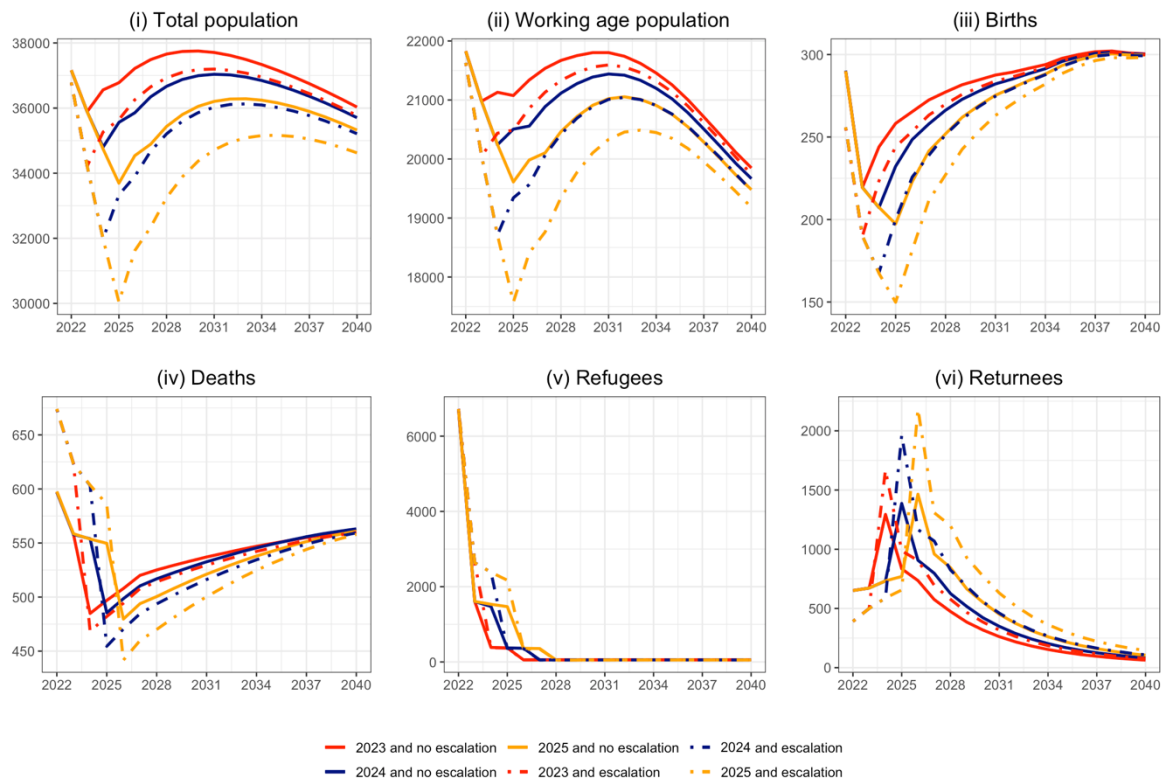
The worst-case scenario is that the war escalates, and that it continues until 2025. Under this scenario, Ukraine would lose around 7m people between 2022 and 2025, and even by the 2030s the population would not get back to its 2022 levels. In this scenario, fertility remains lower, mortality higher, outmigration of refugees stays high and return mobility is limited as long as the war continues. The refugee projections are particularly dramatic, with the cumulative number of people fleeing the war

³⁰ By escalation, we imply further intensification of hostilities in both currently occupied territories of Ukraine and territories bordering the front line, as well as amplification of military aggression against the civilian population, i.e. continuing air strikes targeting civil infrastructure and residential areas, as well as critical infrastructure.

³¹ In all our macro scenarios, total population in 2022 varies between 37.5m and 38m, with 'no escalation' scenarios having a marginally higher population in 2022. This population level is in line with currently available, yet rather limited, estimates of the size of the Ukrainian population at the end of 2022. One has to account for a notable gap in the UN population estimates, which are used as a benchmark for our simulation projections, and national estimates. In the UN data, the total population of Ukraine stood at approximately 43.5m, excluding Crimea and parts of the temporarily occupied territory of the Autonomous Republic of Crimea, the city of Sevastopol and a part of temporarily occupied territories in the Donetsk and Luhansk regions. Population estimates by Ukraine's national statistical office are somewhat lower. However, this disparity does not affect the overall results, as the major focus of the simulation exercise is on the relative magnitude of the population decline during the war and the subsequent recovery.

reaching 14m by the end of 2025. In the worst-case scenario, a post-war population maximum of 35.2m will be achieved in 2035 (19% lower than before the war), followed by a subsequent decline to 34.6m in 2040 (21% below 2021). The dynamic of the working-age population is even more disturbing, as by 2040 it will shrink to 19.2 million, which is 25% below the 2021 level.

Figure 14 / Simulated population projections under six macro scenarios, 2022-2040



Note: The panels depict population dynamics as an average of 10,000 MC simulation rounds. The trajectories depict yearly (non-cumulative) simulated projections.

The longer the war lasts, the greater the number of deaths in all age groups. A longer war will therefore mean fewer workers to contribute to reconstruction. As long as the war lasts, the total number of deaths in 'escalation' scenarios remains above the 'no escalation' scenarios, owing to higher numbers of both military and civilian deaths.³²

However, in all scenarios, Ukraine's population will reach its lowest level in the last year of the war. As soon as the conflict finishes, the population will start to rise again. This will be driven by a sizeable wave of return migration, with survey data showing that safety is the major concern preventing an immediate return for the majority of refugees.³³ Our projections indicate that the majority of refugees will come back in the first five years after the end of the war, with total returns during these years ranging from 4.3m (if the war ends in 2023 without escalation) and 7m (if the war escalates and

³² However, as soon as the war is over, the total number of deaths in the 'escalation' scenarios fall behind the 'no escalation' scenarios for the post-war years. This is because the population will be smaller post-escalation, and as we assume a return to pre-war mortality rates after the end of the fighting, naturally there will be a lower number of deaths than in the post-no escalation scenarios.

³³ <https://data.unhcr.org/en/documents/details/95767>

continues until 2025). This is important for reconstruction, as it suggests that new potential workers will arrive quickly and can support reconstruction if suitable reintegration, retraining and other support policies are in place.

After the post-war population recovery, however, the population still start to decrease again from around 2035 in all scenarios. As outlined, the major refugee returns will come in the first five to ten years after the cessation of hostilities, and our projections expect fertility to recover only to pre-war levels (it is possible that fertility could exceed pre-war levels,³⁴ but this scenario is not included in our simulation exercise).

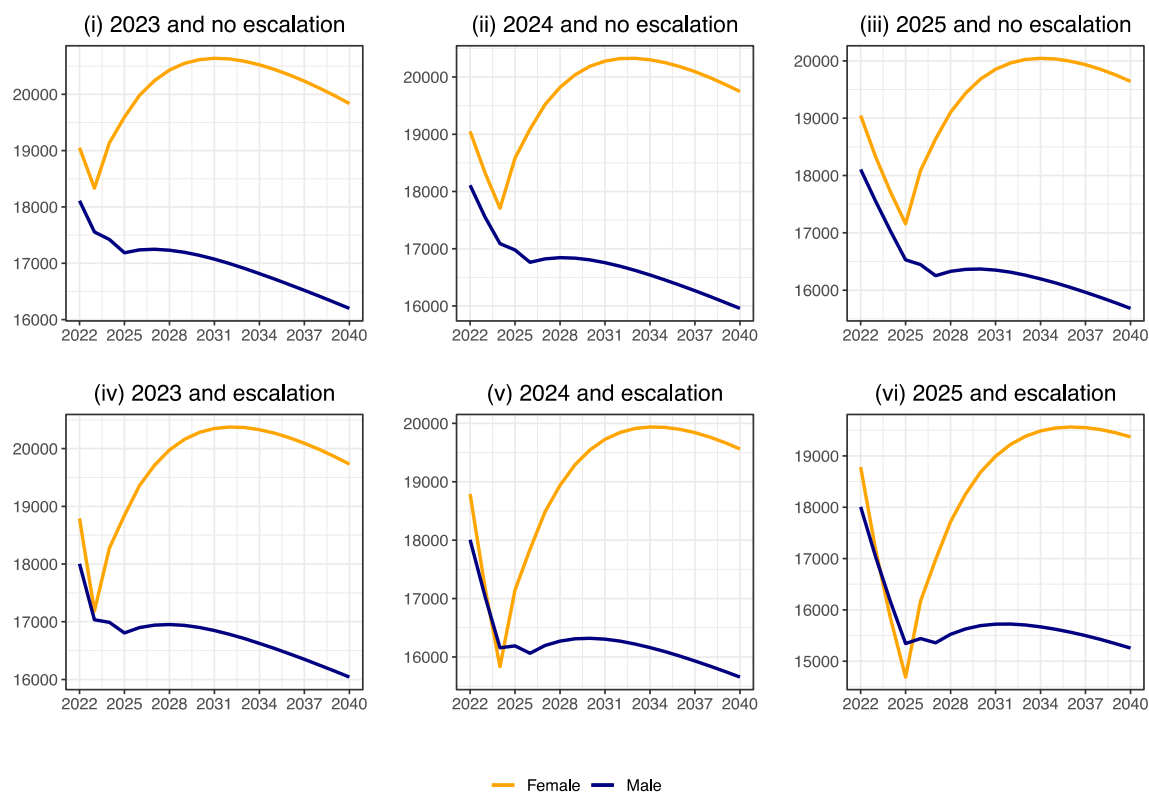
A further escalation of the war would have a major negative impact on Ukraine's population size, irrespective of which year the war ends. However, it is noteworthy that the gap in population outcomes between 'no escalation' and 'escalation' grow wider the longer the war continues. In the scenario assuming the war to be over in 2023, the population drop is 3 pp larger in the 'escalation' case, whereas under the assumption that the war ends in 2025, the gap is 8 pp.

Even in 2040, the gap in projections depending on the duration of the war and the escalation scenario will still be visible. By that year, our projections show that the population will be between 36m (war ends in 2023 and no escalation) and 34.6m (war ends in 2025 and escalation).

The longer the war lasts, the bigger the negative impact on fertility, which will have serious costs for Ukraine for decades to come. Our results show that a longer war will mean ever fewer births and, given that most refugees are women, a continuing outflow of females of reproductive age. Our results broken down by gender further underline this point (Figure 15). Under the scenarios assuming the war to be over in 2025, the female population drop in the last year of the war is most dramatic. Furthermore, under the 'escalation' assumption, the female population drops below the male population, something that is unprecedented in the recent history of Ukraine.

Whenever the war ends, Ukraine's working-age population is set to decline strongly by 2040, posing further challenges for reconstruction. In all scenarios, working-age population will shrink more than the total population (Table 1), with a decline ranging from 22.6% in the 'best-case' scenario to 25.2% in the 'worst-case' one in 2040, relative to 2021. We find that the age-gender population structure in 2040 is drastically different from the pre-war one. Firstly, the decline in births appears very stark, as age cohorts from 0 to 15 years range far below the size of the respective age cohorts in 2021. Secondly, the share of population aged 20 to 55 is notably lower in simulated results for 2040 than in 2021, for both sexes.

³⁴ This would be consistent with rising birth rates in years following WWII. Doepke, M., M. Hazan and Y.D. Maoz (2015), 'The Baby Boom and World War II: A macroeconomic analysis', *The Review of Economic Studies*, Vol. 82(3), pp. 1031-1073.

Figure 15 / Simulated population by gender under six macro scenarios, 2022-2040, '000

Note: The panels depict population dynamics by age as an average of 10000 MC simulation rounds. The trajectories depict yearly (non-cumulative) simulated projections of total male and female population.

3. WHAT ARE THE POLICIES THAT CAN BEST MITIGATE THE DECLINE?

The data and projections in the first part of this chapter show that a lack of workers is going to be one of the central challenges of Ukraine's reconstruction, and there are no easy answers or solutions. Policy should be focused on mitigating the disastrous impact of the war on Ukraine's population numbers. This interacts with other policy areas covered in this report. Policy with regard to the population is not only about getting as many working-age people as possible to Ukraine after the war, but also attracting those with the right skills, and to the areas where they are more needed. Policy action in all three directions needs to be launched as soon as the war ends, as all require major financial resources (especially pro-natal policy) and sufficient time to be adequately implemented.

The right policy will require a combination of four key elements, as outlined below.

3.1. Getting refugees to return

The government's first priority is to get as many refugees as possible to return to Ukraine. To do so, it should take the following steps:

- › **Ensure adequate housing provision for returnees.** Returnees should be provided with information and support regarding housing, especially in regions where returnees lack social networks for information and assistance.³⁵ Housing instruments, conditional on the welfare status of returnees, that may be implemented include: (i) accommodation in emergency housing; (ii) advice and support in accessing social housing; (iii) information and advice on the private housing market; (iv) access to state-assisted mortgage loans.
- › **Help refugees to quickly find work.** Tailored reintegration services related to employment should be established in line with local labour market needs. For a transition period of up to six months, while seeking a job or before receiving business start-up loans, all returnees should be eligible for unemployment benefits. To facilitate faster job search, both among Ukrainians who already returned and among those who are still abroad, digital platforms for job search should be developed.
- › **Create public works programmes.** As a component of economic reintegration programmes, labour-intensive, small-scale public works projects could be financed by local governments and foreign donors, targeted at recovery of local infrastructure and damaged production assets. These projects should be designed to rehabilitate small-scale public infrastructure and clean up war-damaged public assets and simultaneously to create temporary employment for the unemployed and for returning migrants.
- › **Quickly retraining returnees to meet the needs of reconstruction and the post-war economy.** Local authorities and the State Employment Service should offer training and refresher courses to returnees in order to facilitate their reintegration into the domestic labour market. Development of tailored support in professional mentoring, entrepreneurial counselling, training and re-skilling should be prioritised. Re-education programmes should be designed in the spirit of active labour market policies, which are widely implemented in the EU. This would imply a personalised approach towards job seekers, ensuring that skills, knowledge and prior job experience are most effectively used and individual job preferences are considered.
- › **Help returnees to set up businesses and ease access to finance.** As well as training, the government should provide simplified procedures of registration and interest-free business start-up loans. Returnees should be given an opportunity to participate in workshops and individual mentoring concerning private co-funding sources for start-ups, as well as training on establishing professional co-networking and market needs. Business start-up courses (on marketing, taxation, management, legal issues etc.) should be offered to those who would like to develop their own business but lack relevant skills.

The countries currently hosting refugees should also stand ready to provide support. They can help in the following ways:

- › **Institutionalise exchange with Ukrainian authorities.** Information on the profiles and needs of people returning should be communicated to Ukrainian authorities to speed up reintegration. This will allow the receiving country to prepare for the return home of Ukrainian residents and prioritise state/municipal support for those with the most acute needs. Local governments should then be

³⁵ International Centre for Migration Policy Development (2019), 'Return Migration. Background, Practice Examples and Policy Options for Intra-EU Mobility – Focus on Poland', Vienna, October.

responsible for connecting returnees with social protection programmes, assisting in job search and training (re-qualification), as well as temporary housing provision.

- › **Earmark specific financing to support refugee return.** Reintegration programmes should be supported financially by foreign donors as part of the post-war reconstruction programme. Something similar to Assisted Voluntary Return (AVR) programmes³⁶ could be provided for Ukraine, including pre-departure assistance, and financial and practical support for travel arrangements.

3.2. Encouraging new immigration

Ukrainian policy also needs to be tailored towards attracting working-age immigrants from abroad. Relying solely on refugee returns to fill the gaps in the Ukrainian labour market and support reconstruction will not be enough. Even in our most optimistic scenario, fewer than 80% of those who fled the war will return. During the first post-war decade, it will be hard to attract immigrants, owing to the destruction of infrastructure and other societal challenges. However, labour immigration should still be a policy focus in the post-war years, given the labour-intensive nature of reconstruction and the ageing of Ukraine's population. Given that such policy actions require massive effort and huge investments, in time, labour and financial resources, tailoring a pro-immigration policy and taking the first steps towards its implementation need to be done as soon as the war is over.

To do this, the government should prioritise the following:

- › **Loosen restrictions on foreign workers.** Adjustments to legislation are required to make immigration easier for people not classified as highly skilled workers and not working in the field of science and culture. The current version of immigration policy is subject to strict quotas.³⁷ This must change.
- › **Use English as a business language.** One cannot rely on immigrants to already know or to learn Ukrainian quickly. Relying on Russian-speaking immigrants is unrealistic and would dramatically limit the immigration pool.
- › **Look beyond Europe and the former Soviet Union for new workers.** There is little to no chance of attracting notable immigrant flows from countries with higher income levels, more social protection and stronger economic prospects. As a result, immigration sources are likely to remain limited to the South Caucasus, the Middle East, Asia and Africa. Immigrants from the Middle East and Asia will be a completely different ethnic group, culture and religion to Ukrainians. In the context of Ukraine – a mono-ethnic nation – this could lead to substantial societal tensions, posing difficulties for integration.³⁸ Implementation of pro-immigration policy may face strong resistance at various levels. This will require a massive mindset shift across all levels of society.³⁹

³⁶ ICMPD and ECDPM (2013), 'Migration and Development Policies and Practices. A mapping study of eleven European countries and the European Commission', International Centre for Migration Policy Development and European Centre for Development Policy Management, Vienna/Maastricht, May.

³⁷ <https://dmsu.gov.ua/en-home/services/documenting-foreigners/obtaining-immigration-permit.html>

³⁸ <https://www.radiosvoboda.org/a/29202444.html>

³⁹ This may be most challenging for older generations and for people living in rural areas, owing to the stringency of social norms and traditions among the latter.

3.3. Increasing the birth rate

The decline in births as a result of the war should be followed by efforts to increase fertility in the post-war years, in order to at least partly mitigate the projected sharp decline in the working-age population by 2040. However, fertility policies are very costly and, if designed badly, may have a very limited effect, both in terms of magnitude and duration. Ukraine has had a policy aiming to increase fertility in place for decades, yet its effect has been very limited so far.⁴⁰ After a short-lived upsurge in fertility following an increase in the amount of maternal support paid upon birth in 2012-2014, the fertility level dropped to a record low. To design an effective policy, best-practice examples need to be considered. One such example is the fertility-promoting policy launched in Estonia in 2004, which has been upgraded and improved continuously ever since.⁴¹

The design of pro-natal policy in post-war Ukraine needs to be based on the following principles:

- › **Earmarking sufficient resources.** Amounts need to be adequately scaled and correspond to at least average income level for mothers who were unemployed prior to childbirth, and aligned with pre-birth wages of those women who were employed before childbirth. Childcare benefit support needs to be designed on a progressive scale, with a steep increase from the third child onwards.
- › **Childcare support payments for two years after birth.** Childcare leave benefits should be payable at the full rate for at least 12 months and then at reduced rates for the following 12 to 24 months, until the child reaches three years of age. For parents with a short time gap between births, there should be a version of the Swedish 'speed-premium'⁴² – making it possible to prolong a period of full benefit if births are less than 18 months apart and a reduced premium if between 18 and 42 months apart.
- › **Progressively scaled childcare benefits.** The amount and payment period of childcare benefit should increase progressively with each child born in the family and needs to be retained unconditionally on the mother's employment.
- › **Allowing mothers to return to work without losing benefits access.** To encourage maternal employment and to give working women an additional incentive to have children, childcare benefits needs to be retained if mothers who are still eligible for childcare leave benefit go back to work. Such policy design will eliminate the working vs stay-at-home mother income trade-off, as employment will not revoke parents' rights to receive childcare benefits.
- › **Equal rights for fathers.** Fathers should have the same rights when it comes to duration of leave and the amount of childcare payment. Furthermore, splitting the childcare leave should be possible, so that

⁴⁰ https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/undesa_pd_2021_wpp-fertility_policies.pdf

⁴¹ Estonian pro-natal policy is based on three pillars. The first is generosity of payments (for 18 months the amount corresponding to the full salary pre-birth is payable, and a reduced amount for the following 18 months). The second is promotion of subsequent births (parents who space their births closely together – within 30 months – can retain the same level of leave benefit without returning to the labour market in between). And the third is flexibility (easy to combine with continuing employment, as childcare leave benefits are either unaffected or only marginally reduced upon gainful employment; and increased paternal involvement in the leave). However, not only pro-natal policy affects family planning decisions. Long-term state support of families with children is essential, and so the Estonian government is continuously revising and increasing family allowances, which have a steep progressive scale, depending on the number of minor children. https://www.unfpa.org/sites/default/files/pub-pdf/Policy_responses_low_fertility_UNFPA_WP_Final_corrections_7Feb2020_CLEAN.pdf

⁴² <https://www.demographic-research.org/volumes/vol14/4/14-4.pdf>

parents can adjust to the situation dynamically and share the childcare leave period as they find most convenient and financially efficient.

- › **Means-tested family allowance payments until children are 18.** Families need to be continuously supported, with family allowances adjusted in line with the cost of living and inflation and, importantly, the number of children in the household. Family benefits should provide constant support to families, especially large ones, which are most often those facing financial issues, and thus serve as a type of welfare support payment.
- › **Commit to a long-term policy and regularly update it.** When it comes to implementation of pro-natal policies, an important aspect to consider is communication of the policy. To make the policy efficient, people need to know that it will be in place for years to come, so that they have more confidence when planning a family. The government has to continuously revise and upgrade the policy to ensure that the amounts of benefits correspond to living standards and to expand support when the overall economic situation in the country allows for more generous pro-natal action.
- › **Tax advantages.** Tax deductions should apply to families with children under the age of 18, if they are living in the same household as their parents. Importantly, the number and age of minor children should affect the extend of tax deduction, as well as household income, with lower-income families subject to larger deductions.
- › **Promoting pro-family employment conditions.** To foster fertility among females aiming to stay active in the labour market after childbirth, as well as to promote employment of mothers, various steps towards a transition to pro-family employment are needed. These may include flexible working hours and workspaces for parents with minor children, and a more generous care leave system applicable to both mothers and fathers, allowing for non-standard working hours.
- › **Ensuring affordable and accessible childcare for all families.** Provision of childcare is essential for families with young children. Accessibility of affordable childcare has an unambiguous effect on family planning, especially for families with more with one child and/or families in which both parents are employed.

Another aspect contributing to a wider gender gap in employment relates to the labour legislation of Ukraine, which prohibits the use of female labour in difficult and harmful jobs.⁴³ However, a significant part of the gender gap is likely to stem from cultural aspects and the persistence of gender norms, as traditional, patriarchal views remain prevalent in Ukrainian society three decades after the Soviet Union's collapse.⁴⁴

⁴³ Klemparskyi, M.M., H.V. Pavlichenko, R.Y. Prokopiev, L.V. Mohilevskyi and Y.M. Burniagina (2022), 'Gender inequality in the labour market of Ukraine: Challenges for the future', *Work Organisation, Labour & Globalisation*, Vol. 16(2), pp. 140-157. <https://www.jstor.org/stable/48691518>

⁴⁴ <https://eca.unwomen.org/en/where-we-are/ukraine>

3.4. Getting workers to the areas of the country where they will be most needed

The dynamic of IDP movement observed in 2022 suggests that as people moved further away from the front line, many intend to stay in the same or a neighbouring region, although this may not be the case for the Eastern and South-Eastern regions of Ukraine. Liberation of the Kyiv, Chernihiv and Kharkiv regions, ongoing restoration of housing and infrastructure, and a gradual return of residents (observed in the regional dynamic depicted in Figure 11) was one positive example of post-occupation revival of the region. However, the relatively short-lived occupation of the Kyiv, Chernihiv and Kharkiv regions is hardly comparable in terms of the scale of destruction and depopulation with the regions where hostilities have been ongoing for over a year, which have been heavily bombed, such as Mariupol, or which remained longer under occupation and are located close to the current front line, such as Kherson.

As the intensity of military actions and resulting destruction varies drastically between regions, those that require the most material and manpower resources for reconstruction are the ones that are currently most depopulated and heavily destroyed – i.e. the Eastern and South-Eastern regions of Ukraine. Yet with civilian and critical infrastructure, residential buildings and enterprises either heavily damaged or fully destroyed, many refugees or IDPs who fled those regions have nothing to return to. Hence, the reconstruction plan should consider that those who originate from the most affected regions may prefer to settle elsewhere in Ukraine or abroad, as destroyed or heavily damaged housing remains one of the major factors downscaling return intentions both among refugees abroad and IDPs.

The government needs to prioritise the regions that are in greatest need of workers to carry out reconstruction projects and to settle there in the longer term. As government material resources are likely to be limited, so too will be the availability of manpower in the years after the war. Therefore, steps to facilitate the return of IDPs and refugees from Eastern and South-Eastern regions of Ukraine to their home regions is essential. To achieve this, it should take the following steps, which are largely aligned with the actions needed to attract refugees back home, yet with a differentiating focus on the regional aspect:

- › **Housing reconstruction or construction of new dwellings in heavily damaged areas, with a provision of temporary housing in the vicinity.** Attracting people to the heavily destroyed regions after the war ends is largely dependent on the extent and speed of reconstruction. While reconstruction is ongoing, IDPs and returnees to their home regions in Eastern and South-Eastern Ukraine should be provided with adequate temporary housing in the vicinity, so that they can start reintegrating sooner (i.e. entering the local labour market, attending local schools, etc.).
- › **Involvement of working-age IDPs and returnees in the reconstruction of housing and infrastructure.** This step will provide a temporary employment opportunity for returnees and attract more people back. Importantly, there should be direct incentives (other than wages) to engage in renovation works, i.e. renovation of returnees' own damaged houses, or construction of new houses as a replacement for destroyed ones, with subsequent provision of subsidised accommodation.

- › **Region-specific retraining programmes for returnees.** As the economic profile of Eastern and South-Eastern regions is likely to have changed in the post-war period, those returnees who used to work in largely destroyed industries may need additional training and re-education to find employment in other sectors and/or in more technologically advanced jobs. This is particularly relevant for returnees engaged in reconstruction works once those works are completed.

- › **Support for new start-up businesses and for resuming pre-war business activity.** At least initially, financial support will be needed to resume business activity – especially for SMEs. As the structure of economic activity by region will be changing relative to the pre-war period, incentives for setting up new business activity in promising new areas should be given, often in combination with subsidised training and educational programmes that in particular target young people seeking employment opportunities.

TECHNICAL APPENDIX

The simulation model discussed in this technical appendix is employed to project potential future demographic developments for the next two decades. We run a demographic microsimulation, which will replicate the evolution of the Ukrainian population under a number of assumptions on the duration and escalation of the war. Microsimulation techniques are widely used for modelling demographic developments and are a vital tool for analysing structured population models.^{45,46} The stochastic population sub-models take into account demographic uncertainty, and as primary parameters a broad range of factors, including: (i) age- and gender-specific mortality and migration patterns related to military service and moving abroad as a refugee; (ii) microsimulation allows us to easily vary sets of inter-related assumptions; (iii) it allows us to incorporate randomness in crucial demographic indicators such as fertility, mortality, outflow and return of refugees.

Demographic model

To project the demographic future of Ukraine, we employ an elaborate population model, which accounts for age- and gender-specific mortality rates, age-specific fertility rate, age- and gender-specific propensity to migrate (as a refugee fleeing the war), and time-varying return propensity. The model also incorporates population ageing. We consider 101 one-year cohorts that constitute each gender chain: 101 female and 101 male age cohorts. Each main cohort accumulates individuals according to age – from 0 years to those aged 100 years and above. Hence, the total population comprises 202 age-gender cohorts.

To simulate demographic developments, we employ the following population model:

$$P_t = P_{t-1} + B_t + Ret_t - D_t - Ref_t, \quad (1)$$

where

- › P_t and P_{t-1} are total population in years t and $t - 1$ respectively.
- › B_t denotes births in year t and is computed as:

$$B_t = B_t^{boys} + B_t^{girls} = \sum_{i=15}^{49} (P_{i,t-1}^{fem} \cdot f_{i,t} \cdot r^{boys}) + \sum_{i=15}^{49} (P_{i,t}^{fem} \cdot f_{i,t} \cdot (1 - r^{boys})) \quad (2)$$

with B_t^{boys} being the number of boys born in year t , B_t^{girls} being the number of girls born in year t , $P_{i,t-1}^{fem}$ standing for the size of the female population in age cohort i (with $i \in [15,49]$) in year $t - 1$, $f_{i,t}$ denoting fertility rate of females in age cohort i in year t , r^{boys} percentage of boys among newborns.

⁴⁵ Van Imhoff, E. and W. Post (1998), 'Microsimulation methods for population projection', *Population: An English Selection*, pp. 97-136.

⁴⁶ Mielczarek, B. and J. Zabawa (2021), 'Modelling demographic changes using simulation: Supportive analyses for socioeconomic studies', *Socio-Economic Planning Sciences*, Vol. 74, 100938.

› D_t denotes deaths in year t and is computed as:

$$D_t = \sum_{\substack{g \in \{fem, \\ male\}}} \sum_{i=0}^{100} (P_{i,t-1}^g \cdot m_{i,t}^g), \quad (3)$$

where index g denotes gender, index $i \in [0,100]$ denotes age cohort, with $i = 0$ corresponding to newborns and $i = 100$ corresponding to population aged 100 and more, $P_{i,t-1}^{fem}$ and $P_{i,t-1}^{male}$ stand for the size of, respectively, the female and male population in age cohort i (with $i \in [0,100]$) in year $t - 1$, $m_{i,t}^{fem}$ and $m_{i,t}^{male}$ being a mortality rate of, respectively, females and males in age cohort i in year t .

› Ref_t denotes the number of refugees who fled the country in year t , computed as:

$$Ref_t = \sum_{\substack{g \in \{fem, \\ male\}}} \sum_{j=1}^4 P_{j,t-1}^g \cdot mig_{j,t}^g, \quad (4)$$

with index g denoting gender, index $j \in [1,4]$ corresponding to age groups 0-17, 18-34, 35-59 and 60+ years, $P_{j,t-1}^{fem}$ being the female population in age group j in year $t - 1$ and $mig_{j,t}^{fem}$ the probability of females in age group j to flee the war in year t , $P_{j,t-1}^{male}$ being the male population in age group j in year $t - 1$ and $mig_{j,t}^{male}$ is the probability of males in age group j to flee the war in year t .

› Ret_t stands for a number of people who fled the country in years preceding t and who return in year t , which is estimated as:

$$Ret_t = \sum_{\substack{g \in \{fem, \\ male\}}} \sum_{j=1}^4 PR_{j,t}^g \cdot ret_{j,t}^g, \quad (5)$$

with indices g and j defined as above, $ret_{j,t}^{fem}$ and $ret_{j,t}^{male}$ being the probability of, respectively, females and males in age group j , who previously fled the war, to return to Ukraine in year t , $PR_{j,t}^{fem}$ and $PR_{j,t}^{male}$ being the population of, respectively, female and male refugees in age group j in year t .

Assuming \tilde{t} is a year when the war is over, the population of refugees is estimated as follows:

$$\begin{cases} PR_{j,t}^g = Ref_t, \text{ if } t = 1 \\ PR_{j,t}^g = Ref_{t-1} + Ref_t - Ret_{t-1}, \text{ if } 1 < t \leq \tilde{t} \\ PR_{j,t}^g = Ref_{t-1} - Ret_{t-1}, \text{ if } t > \tilde{t} \end{cases} \quad (6)$$

Given that the time span of 18 years considered in our simulation exercise covers the foreseeable period of war and post-war reconstruction, we expect outward and inward migration flows to comprise mainly refugees and returnees, which could be both Ukrainians and foreign nationals residing in Ukraine before the war.

Ageing of the total population and refugee population is modelled, correspondingly, in the following way:⁴⁷

$$\left\{ \begin{array}{l} P_{i,t} = B_{t-1}, \text{ if } i = 0 \\ P_{i,t} = P_{i-1,t-1} + Ret_{i-1,t-1} - D_{i-1,t-1} - Ref_{i-1,t-1}, \text{ if } i \in [1,99] \\ P_{i,t} = P_{i,t-1} + P_{i-1,t-1} + Ret_{i,t-1} + Ret_{i-1,t-1} - D_{i,t-1} - D_{i-1,t-1} - Ref_{i,t-1} - Ref_{i-1,t-1}, \text{ if } i = 100 \end{array} \right. \quad (7)$$

$$\left\{ \begin{array}{l} PR_{i,t} = PR_{i,t-1}, \text{ if } i = 0 \\ PR_{i,t} = PR_{i-1,t-1}, \text{ if } i \in [1,99] \\ PR_{i,t} = PR_{i,t-1} + PR_{i-1,t-1}, \text{ if } i = 100 \end{array} \right. \quad (8)$$

where indices and other input parameters are defined as above. Ageing of population by gender is implemented using the same approach as in equation (2), but with all population measures (total population, births, deaths, refugees, returnees) estimated separately for females and males. A similar approach towards modelling population ageing by age-gender cohorts was used in the microsimulation by Mielczarek and Zabawa,⁴⁸ but our model accounts for refugee and returnee flows rather than usual migration flows.

Simulation procedure

The purpose of the simulation exercise is to explore the potential future evolution of the Ukrainian population under a number of varying external assumptions (macro scenarios) over the period 2022-2040. The demographic simulation is programmed in R and to simulate demographic developments, we rely on the theoretical model described in the previous sub-section.⁴⁹ We then exploit this model and run series of MC simulations to investigate the population dynamics in Ukraine in 2022-2040 under several external assumptions on:

a. Duration of the war:

- a.1 short – will be over by the end of 2023;
- a.2. medium – will be over by the end of 2024;
- a.3. long – will be over by the end of 2025.

b. Further escalation of the war:

- b.1. no major escalations apart from the currently occupied territories;
- b.2. another escalation owing to another attempt to seize other regions, massive attacks on critical and civilian infrastructure.

These assumptions appear crucial for the projected mortality rate, fertility rate, refugee outflow and return mobility of refugees. Specifically, the duration of the war determines the duration of negative effects of military actions on fertility and mortality rates, as well as the duration of intensive outward

⁴⁷ As the oldest age cohort includes all individuals aged 100 and more, we update 101 age cohorts, corresponding to age from 0 to 100+ years at the beginning of each simulated year. Hence, the population in the last age cohort $P_{100,t}$ in year t comprises (i) individuals who were already in this age cohort in year $t - 1$ and survived until year t ; (ii) those who were aged 99 in year $t - 1$ and survived until year t .

⁴⁸ Mielczarek, B. and J. Zabawa (2016), 'Modelling population growth, shrinkage and aging using a hybrid simulation approach: application to healthcare', in *2016 6th International Conference on Simulation and Modeling Methodologies, Technologies and Applications (SIMULTECH)*, pp. 75-83.

⁴⁹ The code is available upon request.

refugee flow and slow return mobility. Further escalation of military actions determines the magnitude of the aforementioned negative effects. Namely, in the case of further escalation, as compared with no escalation, the damaging effects on fertility and mortality rates will be stronger, and the outward refugee flow will be more substantial and the returnee flow smaller.

Hence, we explore six macro scenarios based on the assumptions above:⁵⁰

- i. war ends in 2023 and no further escalation;
- ii. war ends in 2024 and no further escalation;
- iii. war ends in 2025 and no further escalation;
- iv. war ends in 2023 and further escalation;
- v. war ends in 2024 and further escalation;
- vi. war ends in 2025 and further escalation.

For each of the macro scenarios, we consider the pre-war age- and gender-specific median projections for mortality and fertility provided by UN population statistics⁵¹ and then adjust these by randomly drawn factors from the range of values, with those ranges dependent on specific macro scenarios.⁵² The duration and magnitude of the refugee outflow are also shaped by the macro scenarios in place.

Below we explain how the aforementioned six macro scenarios are implemented in the simulation setting and how underlying demographic parameters are randomly adjusted depending on the macro scenario in place.

Fertility

The war has an unambiguously negative effect on the fertility rate, hence the number of births decline due both to an outflow of young women and also the declining birth rate of women who remain in the country.⁵³ Thus, we adjust baseline fertility projections downwards for the years of the war and the adjustment factors are, on average, larger for the scenarios assuming further escalation of the conflict, as the decline in the birth rate is likely to be even higher if the hostilities expand to new territories and intensify.

⁵⁰ Here, we would like to specify that we make no explicit assumptions on the outcomes of the war, but we implicitly assume that Ukraine will restore its territorial independence as of 23 February 2022 as a minimum. Hence, we assume that as a minimum all Ukrainian territories occupied by Russia from 24 February 2022 onwards will be liberated. However, we impose no specific assumption on the status of the Autonomous Republic of Crimea, the city of Sevastopol and a part of the Donetsk and Luhansk regions occupied before 24 February 2022.

⁵¹ To consistently model the effects of the war on mortality and fertility, we considered projections derived before the war and then adjust these randomly according to different scenarios. As the UN projections from 2022 onwards were later altered to incorporate the effect of the war, we substitute the demographic projections for 2022-2025 by the estimates from 2021 as a baseline. Thus, we make an implicit assumption that, if not for the war, the fertility and mortality rates would have remained constant for 2021-2025. Given very minor year-on-year alterations in mortality and fertility rates, this replacement does not distort the long-run dynamics of the indicators. These projections were retrieved from <https://population.un.org/wpp/Download/Standard/MostUsed/>

⁵² For instance, under 'further major escalation', the assumption adjustment factor for mortality among men aged 18 to 60 (conscripted age in Ukraine) will be drawn from a distribution with a larger mean value than adjustment factor for mortality among men aged 18 to 60 under the 'no further major escalation' assumption.

⁵³ <https://tass.com/world/1556337>

Hence, the random adjustment factor for fertility depends largely on further escalation of the war and is simulated as follows:

- › **No further escalation** - As long as the war lasts (until the end of 2023 / 2024 / 2025):
 $\alpha_t \sim U(0.8, 0.9)$ implying a 10 to 20% fertility decline
 - Years after the war until the end of the simulation period:
 $\alpha_t = 1$ recovery of fertility to pre-war projections
- › **Further escalation** - As long as the war lasts (until the end of 2023 / 2024 / 2025):
 $\alpha_t \sim U(0.7, 0.8)$ implying a 20 to 30% fertility decline
 - Years after the war until the end of the simulation period:
 $\alpha_t = 1$ recovery of fertility to pre-war projections

Mortality

The duration and intensity of further military actions affect mortality rates, yet the magnitude of negative effects differ by gender and, for men, by age. Expectedly, the most dramatic upswing in mortality rate occurred in the demographic group in which the majority of soldiers in the Ukrainian Armed Forces belong. During martial law in Ukraine, men aged 18 to 59 may be mobilised and the majority of drafted men are of this age. Women can join the Armed Forces voluntarily, as can men aged 60 and over. However, for the rest of the population also, the mortality rate is higher than would have been the case without the war, as non-combatants can be victims of direct military aggression, or they may suffer physical and mental health issues arising from extreme stress, exhaustion, poor nutrition and the lack or unavailability of medical care.⁵⁴

The magnitude of the mortality increase is largely dependent on further escalation of the war. Thus, we simulate random adjustment factors for mortality as follows:

- › **No further escalation** - As long as the war lasts (until the end of 2023 / 2024 / 2025):
 $\beta_{[0,17],t}^{male}, \beta_{[60,100],t}^{male}, \beta_t^{fem} \sim U(1.01, 1.1)$ implying a 1-10% mortality increase for males aged under 18 and over 60, as well as for females of all age groups
 $\beta_{[18,59],t}^{male} \sim U(1.5, 2)$ implying a 50-100% mortality increase for men aged between 18 and 59
 - Years after the war until the end of the simulation period:
 $\beta_t^{male} = \beta_t^{fem} = 1$ recovery of mortality rates for males and females of all age to pre-war projections.

⁵⁴ <https://www.ukrinform.ua/rubric-society/3641463-demografi-prognozuut-so-u-2023-roci-na-ukrainu-cekae-katastroficne-padinna-narodzuvanosti.html>

- › **Further escalation**
 - As long as the war lasts (until the end of 2023 / 2024 / 2025):
 $\beta_{[0,17],t}^{male}, \beta_{[60,100],t}^{male}, \beta_t^{fem} \sim U(1.1,1.2)$ implying a 10-20% mortality increase for males aged under 18 and over 60, as well as for females of all age groups
 - $\beta_{[18,59],t}^{male} \sim U(2,2.5)$ implying a 100-150% mortality increase for men aged between 18 and 59
 - Years after the war until the end of the simulation period:
 $\beta_t^{male} = \beta_t^{fem} = 1$ recovery of mortality rates for males and females of all age to pre-war projections.

Refugee outflow

As there exists sufficient statistical evidence on the scale and composition of the major refugee flow, we aim to provide a very accurate simulation of the refugee dynamics in 2022, and this will be identical for all macro scenarios. The baseline level of refugee outflow is deduced from available up-to-date statistics on cross-border mobility since the start of the war.⁵⁵ To evaluate the age and gender composition of refugees and their return intentions, existing survey evidence on Ukrainian refugees abroad was used.⁵⁶

Specifically, we derived refugee outflow probabilities for men and women in four age groups – 0 to 17, 18 to 34, 35 to 59, 60 and older – relying on gender and age composition of Ukrainian refugees⁵⁷ from the UNHCR survey, the approximate total number of refugees recorded by the end of 2022 and the estimated population in respective age-gender groups as of 2021. Technically, we first computed the absolute number of refugees in each age-gender group, relying on the approximate estimate of the total refugee outflow of 6m and the age-gender refugee flow composition from the UNHCR survey. We then used the absolute population in corresponding age-gender groups in 2021 to scale the refugee outflow probability. Thus, the refugee outflow probability in 2022 is computed as $mig_{j,2022}^g = \frac{Ref_{j,2022}^g}{P_{j,2021}^g} \cdot 100$, where $Ref_{j,2022}^g$ is the number of refugees of gender g and age group $j \in [1,4]$ corresponding to age groups 0-17, 18-34, 35-59 and 60+, and $P_{j,2021}^g$ is the total population of the respective gender and in the respective age group in 2021. Estimated scaled refugee outflow probabilities in 2022 are then used as a benchmark for further simulation periods.

Additionally, we assumed that during the first two years after the war, following the end of martial law, there will be another wave of male departures from Ukraine. This will consist of (i) men joining their families – wives and children – who fled during the war, settled in the host countries and do not intend to come back to Ukraine,⁵⁸ (ii) men who will leave for work abroad. In both cases this assumption concerns

⁵⁵ The approximate net outflow of Ukrainian refugees amounted to over 7m people by the end of 2022.

<https://data.unhcr.org/en/situations/ukraine>

⁵⁶ <https://data.unhcr.org/en/documents/details/95767>

⁵⁷ According to the most recent UNHCR survey of Ukrainian refugees, the refugee population has the following distribution by age and gender: 19% are males under 18, 3% are males aged 18 to 34, 6% are males age 35 to 59, 3% are males aged over 60, 16% are females aged under 18, 17% are females aged 18 to 34, 27% are females aged 35 to 59, 8% are females aged over 60. The estimates are based on the survey conducted in 43 EU and non-EU countries in August-September 2022 (<https://data.unhcr.org/en/documents/details/95767>).

⁵⁸ According to the UNHCR regional monitoring, over 78% of all surveyed refugees reported family separation, of whom 54% indicated military conscription as the separation reason. Hence, one can safely assume that an absolute majority of refugees who found themselves in such circumstances are women whose husbands or partners stayed in Ukraine because of conscription.

men aged 18 to 59 – those who were not allowed to leave the country as long as martial law was in force and would be allowed to do so once the war is over. To approximate a reasonable share of Ukrainian males who can potentially pursue family reunion abroad, we used the estimated number of females in the same age group (age 18 to 59) who fled the country in 2022 and then assumed that a certain percentage of those will have their husbands/partners joining them abroad after the war.

Specifically, we compute the ratio $\frac{Ref_{j,2022}^{fem}}{P_{j,2021}^{male}}$, where $Ref_{j,2022}^{fem}$ is an absolute number of female refugees in age group $j \in [1,4]$ corresponding to age groups 0-17, 18-34, 35-59 and 60+ who fled the country in 2022, and $P_{j,2021}^{male}$ is the male population in the respective age groups in 2021. Thus, we approximate a share of the male population in the respective age group whose wives/partners fled the country during the first year of the war.

Below, we specify how the random simulation of refugee outflow was tailored, with exact distribution specifications available in Table A1:

- › **Year 2022 (all scenarios)** $mig_{j,2022}^g \sim U\left(0.9 \frac{Ref_{j,2022}^g}{P_{j,2021}^g}, 1.1 \frac{Ref_{j,2022}^g}{P_{j,2021}^g}\right)$ implying a variation of share of refugees in each of the eight gender-age groups from 90% to 110% of the refugee shares $mig_{j,2022}^g$ estimated based on existing statistical evidence.
- › **No further escalation**

 - As long as the war lasts (until the end of 2023 / 2024 / 2025): $mig_{j,t}^g \sim U\left(0.27 \frac{Ref_{j,2022}^g}{P_{j,2021}^g}, 0.33 \frac{Ref_{j,2022}^g}{P_{j,2021}^g}\right)$ share of refugees in each of the eight gender-age groups varies from 27% to 33% of the 2022 level, implying that the overall yearly refugee flow is around three times lower than in the first year of the war.
 - First two years after the war for males in age groups 18-34 and 35-59: $mig_{j,t}^{male} \sim U\left(0.1 \frac{Ref_{j,2022}^{fem}}{P_{j,2021}^{male}}, 0.15 \frac{Ref_{j,2022}^{fem}}{P_{j,2021}^{male}}\right)$ implying that around 10% to 15% of men aged 18-34 and 35-59 whose wives/partners reside abroad as refugees will emigrate to pursue family reunion during the first two years after the war (after martial law is lifted).
 - Years after the war until the end of the simulation period: $mig_{j,t}^g \sim U(0.001, 0.002)$ outward migration corresponding to the normal pre-war emigration flow.

- › **Further escalation**
- As long as the war lasts (until the end of 2023 / 2024 / 2025):

$$mig_{j,t}^g \sim U \left(0.45 \frac{Ref_{j,2022}^g}{P_{j,2021}^g}, 0.55 \frac{Ref_{j,2022}^g}{P_{j,2021}^g} \right)$$
 share of refugees in each of the eight gender-age groups varies between 45% and 55% of the 2022 level, implying that the overall yearly refugee flow is around half the level seen in the first year of the war.
 - First two years after the war for males in age groups 18-34 and 35-59:

$$mig_{j,t}^{male} \sim U \left(0.1 \frac{Ref_{j,2022}^{fem}}{P_{j,2021}^{male}}, 0.15 \frac{Ref_{j,2022}^{fem}}{P_{j,2021}^{male}} \right)$$
 implying that around 10% to 15% of men aged 18-34 and 35-59 whose wives/partners reside abroad as refugees will emigrate to pursue family reunion during the first two years after the war (after martial law is lifted).
 - Years after the war until the end of the simulation period:

$$mig_{j,t}^g \sim U(0.001, 0.002)$$
 outward migration corresponding to the normal pre-war emigration flow.

Returnee inflow

As we have very scarce evidence on the up-to-date returnee flow, and as return intentions of Ukrainian refugees are highly uncertain,⁵⁹ we simulate future return mobility under a simplistic assumption that return intentions will not systematically differ according to the age and gender of refugees. Hence, we align the simulated shares of returnees in eight age-gender groups, defined above, to the estimated shares of refugees in specific age-gender groups. We assume that the full-scale return mobility will start only in the first year after the war, and that only a marginal share of refugees will move back to Ukraine as long as the war continues. Naturally, the dynamics of return mobility during the war years will depend on further escalation of the military action.

Below, we specify how the random simulation of refugee return flow was tailored, with exact distribution specifications available in Table A2:

- › **No further escalation**
- As long as the war lasts (until the end of 2023 / 2024 / 2025):

$$ret_{j,t}^g \sim U \left(0.2 \frac{Ref_{j,2022}^g}{P_{j,2021}^g}, 0.3 \frac{Ref_{j,2022}^g}{P_{j,2021}^g} \right)$$
 share of returnees in each of the eight gender-age groups varies between 20% and 30% of the estimated share of refugees in 2022.
 - Years after the war until the end of the simulation period:

$$ret_{j,t}^g \sim U \left(0.7 \frac{Ref_{j,2022}^g}{P_{j,2021}^g}, 0.8 \frac{Ref_{j,2022}^g}{P_{j,2021}^g} \right)$$
 steady return mobility aligned to the outward migration in the respective age-gender group in 2022.⁶⁰

⁵⁹ Existing data on border crossings with Ukraine are rather unreliable, as they include a high share of commuters, volunteers and refugees travelling back to Ukraine for a short time period. Hence, the estimate of people who entered Ukraine since the start of the Russian invasion cannot be used to approximate the number of returnees.

⁶⁰ Although return mobility rates are steady for all post-war years, the number of returnees will decline over time, as returnees are drawn from the total population of refugees, which will shrink with each subsequent year.

- › **Further escalation**
- As long as the war lasts (until the end of 2023 / 2024 / 2025):

$$ret_{j,t}^g \sim U \left(0.1 \frac{Ref_{j,2022}^g}{P_{j,2021}^g}, 0.2 \frac{Ref_{j,2022}^g}{P_{j,2021}^g} \right)$$
 share of returnees in each of the eight gender-age groups varies between 10% and 20% of the estimated share of refugees in 2022.
 - Years after the war until the end of the simulation period:

$$ret_{j,t}^g \sim U \left(0.7 \frac{Ref_{j,2022}^g}{P_{j,2021}^g}, 0.8 \frac{Ref_{j,2022}^g}{P_{j,2021}^g} \right)$$
 steady return mobility aligned to the outward migration in the respective age-gender group in 2022

Simulation cycle

Each round of the MC simulation proceeds as follows. The entire simulation procedure runs on the gender-age cohort level (202 age-gender cohorts). Thus, all input data is provided on the age-gender cohort level and all MC estimations are implemented on the cohort level in each simulation period, with further aggregation to the population total estimates for each period (year). The input data for our simulation is the population of Ukraine by gender and single-year age groups as of 2021, as well as median projections for fertility, male and female mortality rates by single-year age groups for the years 2022-2040, provided by UN population statistics.⁶¹

We start a single MC simulation loop by drawing the random adjustment factors for a given (MC) iteration, depending on the specific macro scenario in place and following the procedures outlined above. We then modify yearly age-specific fertility rates, male and female mortality rates, male and female refugee probability, and male and female return probability by the randomly drawn adjustment factors and store the matrices containing the aforementioned demographic parameters, which are used in the current MC simulation loop.

Next, we simulate population in year $t = 1$, which is 2022, following the sequence:

- i. simulate number of birth in year $t = 1$ following equation (2);
- ii. simulate number of deaths in year $t = 1$ following equation (3);
- iii. simulate number of refugees in year $t = 1$ following equation (4);
- iv. simulate number of returnees in year $t = 1$ following equation (5);
- v. update the refugee population matrix following equation (6) and account for ageing of refugee population following equation (8);
- vi. estimate population in 2022 following equation (1) and implement population ageing following equation (7).

In the next period $t = 2$, which is 2023, we repeat the simulation procedure and store the simulation results. By repeating the same loop over 19 periods, we complete a single simulation cycle and store population dynamics for all 19 periods, corresponding to the years 2022-2040. We then run the simulation loop for $n = 10,000$ times, randomly drawing the adjustment factors on each iteration, and compute the average population dynamics indicators over all $n = 10,000$ iterations.

⁶¹ <https://population.un.org/wpp/>

Table A.2 / Upper and lower limits of uniform distribution used for simulation of returnee inflow across gender-age cohorts and across six macro scenarios

Macro scenario	Years	Males 0-17	Males 18-34	Males 35-59	Males 60+	Females 0-17	Females 18-34	Females 35-59	Females 60+
Ends in 2023 / no escalation	2022-2023	[10.62, 12.98]	[1.77, 2.17]	[2.10, 2.57]	[2.12, 2.59]	[11.27, 13.78]	[10.54, 12.88]	[8.72, 10.66]	[3.16, 3.86]
	2025+	[21.24, 25.96]	[3.55, 4.34]	[4.21, 5.14]	[4.24, 5.18]	[22.55, 27.56]	[21.07, 25.76]	[17.44, 21.32]	[6.32, 7.72]
Ends in 2024 / no escalation	2022-2024	[10.62, 12.98]	[1.77, 2.17]	[2.10, 2.57]	[2.12, 2.59]	[11.27, 13.78]	[10.54, 12.88]	[8.72, 10.66]	[3.16, 3.86]
	2025+	[21.24, 25.96]	[3.55, 4.34]	[4.21, 5.14]	[4.24, 5.18]	[22.55, 27.56]	[21.07, 25.76]	[17.44, 21.32]	[6.32, 7.72]
Ends in 2025 / no escalation	2022-2025	[10.62, 12.98]	[1.77, 2.17]	[2.10, 2.57]	[2.12, 2.59]	[11.27, 13.78]	[10.54, 12.88]	[8.72, 10.66]	[3.16, 3.86]
	2026+	[21.24, 25.96]	[3.55, 4.34]	[4.21, 5.14]	[4.24, 5.18]	[22.55, 27.56]	[21.07, 25.76]	[17.44, 21.32]	[6.32, 7.72]
Ends in 2023 / escalation	2022-2023	[6.37, 7.79]	[1.06, 1.30]	[1.26, 1.54]	[1.27, 1.55]	[6.76, 8.27]	[6.32, 7.73]	[5.23, 6.39]	[1.90, 2.32]
	2025+	[21.24, 25.96]	[3.55, 4.34]	[4.21, 5.14]	[4.24, 5.18]	[22.55, 27.56]	[21.07, 25.76]	[17.44, 21.32]	[6.32, 7.72]
Ends in 2024 / escalation	2022-2024	[6.37, 7.79]	[1.06, 1.30]	[1.26, 1.54]	[1.27, 1.55]	[6.76, 8.27]	[6.32, 7.73]	[5.23, 6.39]	[1.90, 2.32]
	2025+	[21.24, 25.96]	[3.55, 4.34]	[4.21, 5.14]	[4.24, 5.18]	[22.55, 27.56]	[21.07, 25.76]	[17.44, 21.32]	[6.32, 7.72]
Ends in 2024 / escalation	2022-2025	[6.37, 7.79]	[1.06, 1.30]	[1.26, 1.54]	[1.27, 1.55]	[6.76, 8.27]	[6.32, 7.73]	[5.23, 6.39]	[1.90, 2.32]
	2026+	[21.24, 25.96]	[3.55, 4.34]	[4.21, 5.14]	[4.24, 5.18]	[22.55, 27.56]	[21.07, 25.76]	[17.44, 21.32]	[6.32, 7.72]

IMPRESSUM

Herausgeber, Verleger, Eigentümer und Hersteller:

Verein „Wiener Institut für Internationale Wirtschaftsvergleiche“ (wiiw),
Wien 6, Rahlgasse 3

ZVR-Zahl: 329995655

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Offenlegung nach § 25 Mediengesetz: Medieninhaber (Verleger): Verein "Wiener Institut für Internationale Wirtschaftsvergleiche", A 1060 Wien, Rahlgasse 3. Vereinszweck: Analyse der wirtschaftlichen Entwicklung der zentral- und osteuropäischen Länder sowie anderer Transformationswirtschaften sowohl mittels empirischer als auch theoretischer Studien und ihre Veröffentlichung; Erbringung von Beratungsleistungen für Regierungs- und Verwaltungsstellen, Firmen und Institutionen.

