MIRREM

Measuring Irregular Migration

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Irregular Migration: What Can Mortality Reveal?

MIrreM Briefing Paper

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Executive Summary

This study explores mortality data as a basis for estimating the irregular migrant population, a technique labelled “mortality extrapolation”. Using Belgian data, it demonstrates that mortality can be a reliable and methodologically sound basis for gauging not only the size of mobile populations, but also their evolution over time, offering granularity in terms of age groups and gender. The technique boosts significant advantages over traditional methods, such as reliance on well-established demographic tools, unbiased observation of basic indicators and a transparent basis for calculating extrapolation factors. Given the type of data that it requires, the method offers promising prospects for broader international implementation.

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ACRONYMS

COD	Causes Of Deaths: a EUROSTAT database compiling mortality data from the EU member countries
EU	The EU acronym is used loosely in this report. Depending on the context, it refers to the European Union, but also to the EU/EFTA total

THE MIRREM PROJECT

MIrreM examines estimates and statistical indicators on the irregular migrant population in Europe as well as related policies, including the regularisation of migrants in irregular situations.

MIrreM analyses policies defining migrant irregularity, stakeholders' data needs and usage, and assesses existing estimates and statistical indicators on irregular migration in the countries under study and at the EU level. Using several coordinated pilots, the project develops new and innovative methods for measuring irregular migration and explores if and how these instruments can be applied in other socio-economic or institutional contexts. Based on a broad mapping of regularisation practices in the EU as well as detailed case studies, MIrreM will develop 'regularisation scenarios' to better understand conditions under which regularisation should be considered as a policy option. Together with expert groups that will be set up on irregular migration data and regularisation, respectively, the project will synthesise findings into a Handbook on data on irregular migration and a Handbook on pathways out of irregularity. The project's research covers 20 countries, including 12 EU countries and the United Kingdom.

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KEYWORDS

Irregular Migration; Statistics; Migrant Demography, Mortality

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1. INTRODUCTION

The primary objective of this pilot study is to evaluate the feasibility and quality of a new estimation tool for measuring irregular migrant populations using mortality indicators, a method referred to as mortality extrapolation. A key focus is to assess whether this tool can be adapted to various European contexts, highlighting the conditions and data requirements for replication.

The study raises pivotal research questions about the availability and reliability of mortality data, the assumptions regarding mortality rates for irregular versus regular migrants, and the outcomes' validity in terms of accuracy, reproducibility, and granularity. Although the pilot uses Belgian data as a test case, the method is intended to be scalable to other European countries, offering significant potential for broader applications.

The foundation of the methodological approach lies in demographic principles, where mortality risks follow predictable patterns based on age and gender. Demographers often estimate the expected number of deaths within a given population, as commonly done in life insurance calculations (Namboodiri & Suchindran, 1987). This study reverses that logic: by analysing mortality data (age, gender, and number of deaths), we can infer the size and composition of the population that produced those deaths.

Mortality data from irregular migrants are obtained by cross-referencing identity information in the general mortality registry with the official population register. This cross-check identifies each deceased individual as either an official Belgian resident ("linked deaths") or as someone not registered in the population register ("unlinked deaths"). Once unlinked deaths are identified, life table methods are applied to estimate (i.e., extrapolate) the characteristics of the broader non-registered resident population.

However, not all non-registered residents are necessarily irregular. Documented foreign citizens may also be present in Belgium for short stays, during which some deaths occur. A final step in the procedure is therefore needed to extract the irregular population from the broader pool of unregistered residents. Although proven demographic tools underlie mortality extrapolation, challenges remain, particularly in accurately gauging mortality risks among unregistered and irregular populations.

If validated, the method of mortality extrapolation offers several advantages over traditional techniques for estimating irregular migrant stocks. Crucially, it rests on a robust empirical and theoretical foundation in demography, avoiding many biases that plague conventional observational methods. The use of mortality data, which is highly reliable and regularly updated, ensures that estimates are anchored in measurable phenomena, making this method a potentially transformative tool for migration research:

2. CONCEPTS AND DEFINITIONS

The success of any estimation tool depends on the clarity and precision of its concepts. In this pilot study, we extend beyond traditional definitions of irregular migration to focus on a broader population of "non-registered residents", individuals physically present on Belgian soil without formal registration in the population register. This category encompasses a wide range of people with regular, irregular, or hybrid statuses: tourists, visitors, individuals in transit through Belgium, visa-holders, diplomats, and EU and EFTA[1] citizens who, despite having the legal right to register, who , remain unregistered who remain unregistered despite their legal right to register. Their partial citizen-like rights (based on EU nationality, for example) enable them to opt out of registration. Because this position does not fit neatly into the classic citizen/non-citizen divide, it is sometimes referred to as "denizenship" (Walker, 2008).

In Belgium, these denizens are predominantly citizens of neighbouring countries who live in border regions and distribute their employment, social networks, real estate ownership, education, and healthcare use across both sides of the border. Shared languages across the Dutch, German, and French borders, along with bilateral agreements providing Belgian healthcare coverage for Dutch and French citizens, all contribute to this fluidity. Ultimately, this allows mobile citizens to choose the most advantageous arrangements in terms of cost of living, availability of services, taxation, and more.

This expansive definition of the unregistered population aligns with what Kraler (2023) describes as a "mobile population." Because mortality data distinguishes only between registered and unregistered individuals without revealing their legal status, the inclusion of all these groups is necessary.

The operationalisation of this broader category is essential for this study's approach. Mortality registration in Belgium captures both registered and unregistered individuals, enabling us to estimate the size of the unregistered population. Within this large group, further analysis considers nationality, visa status, and other contextual data (e.g., tourism and visa statistics) to distinguish between regular and irregular migrants. By refining this population in later stages, we can focus more precisely on irregular migration.

Throughout this study, we use the term "internationally mobile citizens" to refer to this broadly defined, unregistered population. This general concept captures Europe's free movement context, encompassing individuals who may not traditionally be considered

[1] EU refers to the European Union member states, EU+ refers to the same countries plus the EFTA-countries (Norway, Iceland, Switzerland and Liechtenstein). Today this largely coincides with the Schengen free travel zone, with the exception of Ireland and Cyprus.

irregular migrants. Although the scope is initially broadened, this approach ultimately facilitates a more nuanced demographic analysis of irregular migrant populations.

3. METHODS AND DATA

3.1 METHODS

3.1.1 Description of the method

This study employs a two-step method for estimating irregular migrant populations using mortality extrapolation. In the first step, we estimate the total population of unregistered individuals, categorised by age, gender, and national origin, without distinguishing between regular and irregular statuses. The second step refines this estimate by subtracting the number of regular-status individuals, isolating the irregular population

Mortality extrapolation functions as a multiplier method, grounded in well-established demographic life table techniques (Rodriguez Sanchez & Tjaden, 2023). We identify deaths of unregistered individuals by linking national mortality records to the population register; any deaths that remain unmatched are attributed to the unregistered population. Mortality risks (the probability of death for a specific age and gender group) are then used to estimate the living population. For example, if the mortality risk is 1/10,000, one death would imply a living population of 10,000 individuals in that subgroup. Because mortality risks vary by age, gender, and population, we use an appropriate set of mortality risks to calculate the total living population across all subgroups.

The method assumes that the mortality risks for unregistered individuals are similar to those of recent legal immigrants from the same regions. Many recent immigrants have resided in Belgium under irregular statuses, tourist visas, or asylum seeker positions before regularizing (van Meeteren, 2014). Therefore, recent legal immigrants serve as a proxy for mortality risks among unregistered populations. These risks generate age- and gender-specific extrapolation factors, which are applied to the number of unregistered deaths to derive population size.

In the second step, the number of regular-status individuals—such as tourists, visa-holders, and diplomats, is subtracted from the total unregistered population. Data for these groups come from tourism statistics, visa records, and asylum data. Those who are not covered by visa, asylum, or tourism counts represent the estimated irregular migrant stock.

3.1.2 Methodological advantages

This method offers several advantages over traditional approaches for estimating irregular migration. Unlike techniques based on selective observations (e.g., police records or border apprehensions), mortality data is comprehensive and largely free from administrative biases. Mortality risks are stable demographic parameters (Bengtsson, 2006), making life table methods a reliable basis for population estimation.

Moreover, mortality extrapolation produces detailed demographic estimates, including age and gender breakdowns. Such specificity allows comparisons across countries and over time, making the method particularly valuable for international studies of irregular migration.

3.1.3 Stocks and flows

Mortality extrapolation provides estimates of population stocks, the number of irregular migrants present in a country at a particular point in time. It does not directly measure flows, or movements of migrants over time. However, by expressing stock data in terms of person-years (Van Hook, 2024), and converting flow data into stock estimates if the duration of stay is known, the method can facilitate comparisons of irregular migrant stocks across different periods.

3.1.4 Limitations

Several limitations should be noted. First, mortality is a rare event, especially in younger populations, which can lead to instability in estimates of smaller subgroups. Consequently, data often need to be aggregated over multiple years to yield sufficient sample size. Another challenge is the assumption that unregistered and irregular populations share the same mortality risks as recent legal immigrants. In reality, irregular migrants may face unique health vulnerabilities (Lafaut et al., 2019, PICUM, 2022).

Finally, while the method is well-suited for national-level estimates, it may be less precise for detailed geographic breakdowns, particularly in smaller regions or rural areas. The estimates are generally more reliable in urban centres like Brussels, where larger numbers of irregular migrants reside.

3.2 DATA

3.2.1 Data description

This study relies on three primary data sources. First, we use mortality data that distinguishes between registered and non-registered individuals. Second, we need data on mortality among recent legal immigrants to estimate mortality risks for the unregistered population. Third, we require data on regular-status unregistered residents (e.g., tourists, asylum seekers, visa holders) to separate them from irregular migrants within the broader unregistered group.

For this pilot, Belgian mortality data from the national statistical agency (STATBEL) was used. The dataset encompasses all deaths from 1998 to 2016, including age, gender, country of origin, and a marker indicating whether the individual was present in the population register. The data originates from the national Cause of Death (COD) registration. Unregistered deaths were identified by linking this mortality dataset to the population register, with any unlinked cases classified as deaths among unregistered individuals.

A second dataset contains the entire population of recent legal immigrants recorded in the national population register, alongside immigration and death events for the period 2011–2016. This dataset is used to calculate empirical life tables for mortality risks by age, gender, and country of origin. For enhanced accuracy, empirical life tables were replaced by

matching model life tables to stabilise the observed mortality estimates over the life course, using the MORTPAK software (United Nations Population Division, 2024).

Finally, data on regular-status visitors (tourists, short-term visa holders, asylum seekers, and diplomats) was gathered from official tourism, asylum, and visa statistics (Kraler, 2023). This information enables distinguishing the irregular population from other non-registered groups.

3.2.2. Summary statistics

Over the 14-year observation period, the dataset identified 26,776 unlinked deaths, of which 23,926 were considered after excluding deaths of newborns. Approximately 85% of these unlinked deaths involved EU+(EFTA) citizens, leaving about 3,500 deaths among non-EU nationals. For analytical stability, data for non-EU nationals was aggregated into larger regional groups (e.g., North Africa, Sub-Saharan Africa) across three time periods: 1998–2006, 2007–2011, and 2012–2016. This periodic structure reflects a twofold consideration. First, yearly numbers of deaths in regional groups are insufficient to produce stable estimates, dictating a further aggregation of data over several years. Second, keeping the entire 2007-2011 timeframe in the same observational unit allows to check whether new relaxed regularisation rules issued in 2009 are captured by our outcomes. According to debates in Belgian Parliament, those relaxed rules lead to around 28.000 extra regularizations in the first 2 years (Belgian Senate, 2011). If mortality extrapolation produces accurate outcomes, it should be able to pick-up this effect as a concomitant reduction in the irregular status population during those years. In other words, isolating policy-shift effects in the 2007-2011 period is also a performance test for the method.

In the second dataset, mortality data for recent legal immigrants covered deaths occurring within 10 years of their arrival, ensuring the proxy was sufficiently close to the non-registered population.

3.2.2 Limitations of the data

While the data is comprehensive, a few limitations arise. One concern is the delay in recording some individuals who may have gained legal residency shortly before death but were not yet registered at the time of death. However, such short delays are not expected to significantly distort the estimates.

Another issue is the over-representation of deaths among newborns in the unregistered population. These cases, likely infants dying before their birth was officially registered, are not relevant to migration and were excluded from the analysis. Similarly, the presence of foreign euthanasia applicants in Belgium, particularly from neighbouring countries, could distort estimates for EU citizens (Euronews, 2023). These factors mainly affect estimates for EU+(EFTA) citizens, while estimates for non-EU nationals—the primary focus of this study—remain less impacted.

4. RESULTS

4.1. Overall estimates of unregistered and undocumented populations

As previously outlined, the mortality extrapolation technique produces two levels of detail regarding population estimates. The first and most general level pertains to the unregistered population present within Belgian borders, as it would appear in a hypothetical complete headcount on an average day. This count separates members of the official population from all other individuals who are physically present but unregistered. According to our most recent mortality-based estimation (2012-2016), the total unregistered population in Belgium amounts to around **489,000** people. For context, Belgium's official population was approximately 11.3 million during that period.

The split between EU+(EFTA) and non-EU fractions and the composition of both populations by age and gender is revealed in Figures 4.1 and 4.2. Horizontal bars in the population pyramid represent the size of each age group. Male estimated population is always depicted in blue on the left-hand side of the pyramid, and female estimated population in orange on the right-hand side. Population totals are calculated by simply adding up age group estimates. In both cases results show that unregistered populations are slightly male dominated and rather young, but children and adolescents are less strongly represented than young adults. Over time, figures show a consistent downward trend in EU+(EFTA) unregistered population, whilst its non-EU counterpart initially shrunk in the 2007-2011 time interval but quickly took up again towards the end of observation. Mortality extrapolation indeed registers the policy-shift effect from 2009: 28,000 extra regularisations based on official statistics are mirrored by a 36,000 decrease in the unregistered non-EU population according to mortality extrapolation. However, mortality-based extrapolations also observe that those effects eroded quickly thereafter.

Within the 195,000 non-EU unregistered individuals depicted in Figure 4.2, the irregular status subpopulation can be estimated at around **112,000** people. This number is calculated by starting from the 195,000 non-EU total and simply subtracting those having a documented status: 50,000 valid status asylum applicants awaiting the outcome of their procedures, 14,000 holders of issued and extended Schengen C-visas, 10,000 diplomatic staff and 9,000 tourists from mainly visa-waivered countries.

Similar calculations can be performed for the EU+(EFTA) population. Within the estimated total of 294,000 unregistered non-EU individuals, about 77,000 can be identified as regular tourists or members of the diplomatic community, leaving the remaining **217,000** in a hybrid status as "denizens". They are not conventionally seen as undocumented immigrants, but they are either overstaying their legal residence period or have no formal registration at all. This impressive number again underscores the complexity of tracking irregular EU citizens who benefit from free movement rights.

Table 1 Estimated unregistered population according to legal status (Belgium 2016)

	Non-EU+	*EU+(EFTA)*	***TOTAL***
Irregular	**112,000**	(217,000)	**(339,000)**
Regular	83,000	(77,000)	**(150,000)**
TOTAL	**195,000**	**294,000**	**489,000**

4.2. Compositional trends

As can again be observed in Figures 4.1 and 4.2, the composition of unregistered populations in Belgium also changed over time. Several trends can be identified. The first observation is that the number of children and young adults seems to drop in both EU and non-EU unregistered populations. Second, skewed gender distribution towards male dominance further increases over time. From our analyses it is not apparent to what degree male dominance was already present at the moment of entry into Belgium. However, the 2009 regularization policy-shift affecting non-EU unregistered citizens explicitly favoured women and their school going children, putting single men seeking regularisation of their residential status in a disadvantaged position. This partially explains the growing male dominance: from 54% to 58% and even briefly up to 61% immediately after the new policy came into effect. The same mechanism also explains dropping numbers of children in the non-EU unregistered population.

The third observation is that unregistered populations in Belgium are ageing at a fast pace. The proportion of unregistered residents over 50 years old grew by 22% among EU+(EFTA) citizens and by a remarkable 80% among non-EU nationals. This is not necessarily worrying in the EU+(EFTA) group where affluent expats and pensioners make out much of the population, and because they freely opted for non-registration. But in the non-EU group where ageing progresses even more rapidly, it indicates that absence of large-scale regularisation measures in Belgium after 2011 did not force return migration but instead caused an increasing population nearing the end of their productive lives whilst finding themselves in a very precarious situation without pension rights or full access to health care.

To sum up, the mortality extrapolation technique produces age pyramids that align closely with known demographic characteristics of these populations, and it quite adequately reproduces known trends based on policy-shifts.

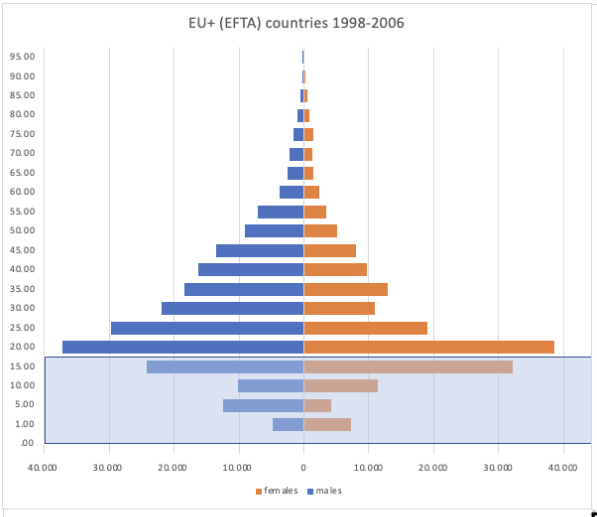
4.3. Detailed regional origins

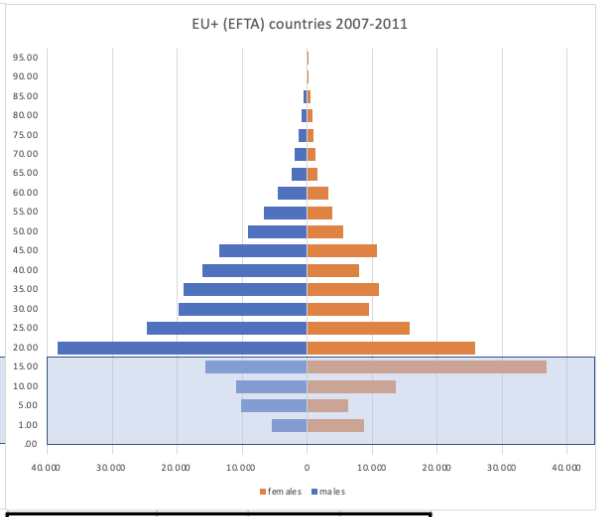
Figures 4.3 to 4.5 further break down the regional origins of the non-EU mobile population based on mortality data extrapolation. While these figures focus on non-EU countries, Eastern Europe is also included as a geographically static region despite several Eastern European countries joining the EU during the 5th enlargement (2004), as well as Romania and Bulgaria in 2007, and Croatia in 2013.

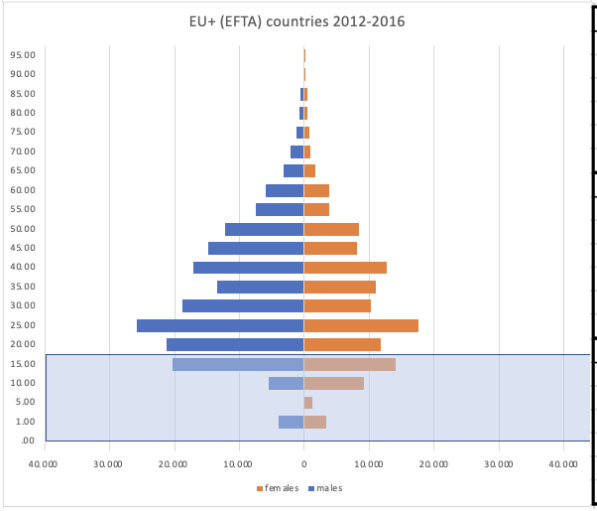
Around the year 2000, Northern Africa was the dominant region of origin for non-EU mobile citizens, but this changed over time. The sharp decline in Northern African nationals, combined with a strong increase from Eastern Europe, led to a shift in dominance to Eastern

European origins by 2011. Outside of Europe, only Sub-Saharan Africa continued to show growth in the last period, and it is noteworthy that Sub-Saharan Africa is the only region where women dominate, comprising about 59% of the mobile population from this region. In contrast, women from Northern Africa and Turkey represented only about 20% of the mobile population, making them the most male-dominated regions.

Although French nationals are not included in Figures 4.3 to 4.5, they represent a significant portion of the mobile population in Belgium. French citizens alone make up a larger group than all non-EU and Eastern European citizens combined, with an estimated 185,000 French nationals present in the last observation period, down from 250,000 at the turn of the millennium.

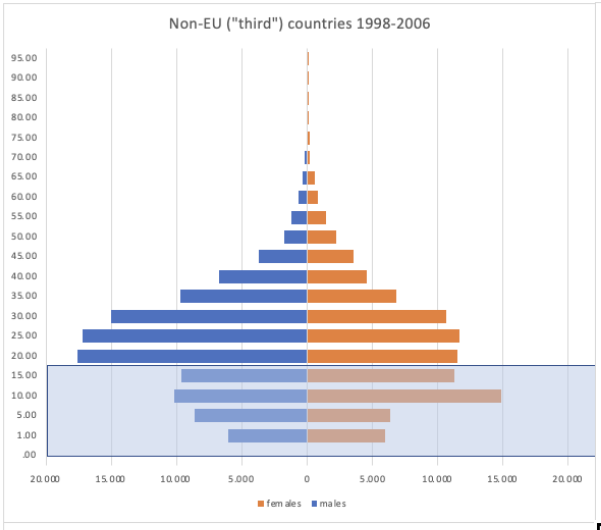


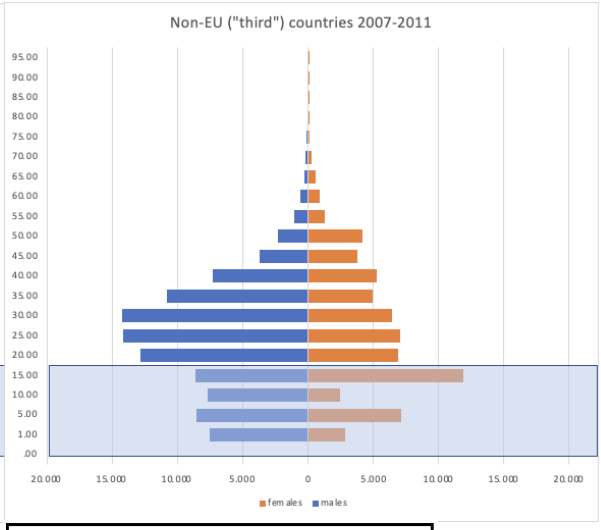


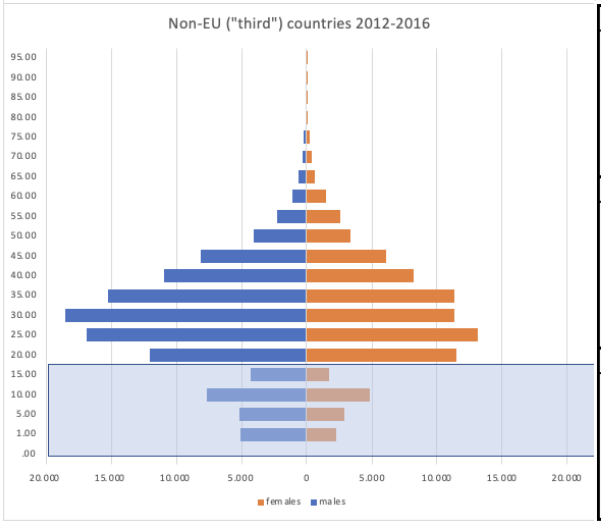


1998-2006	Male	Female	Total
Total population	217000	171000	388000
Gender %	56%	44%	100%
Mean age	31,3	28,4	30,0
Population 20+	165000	116000	281000
Population 40+	58000	35000	93000
Population 50+	28000	17000	45000
2007-2011	**Male**	**Female**	**Total**
Total population	202000	164000	366000
Gender %	55%	45%	100%
Mean age	32,0	27,9	30,1
Population 20+	160000	99000	258000
Population 40+	58000	37000	94000
Population 50+	28000	18000	46000
2012-2016	**Male**	**Female**	**Total**
Total population	175000	119000	294000
Gender %	59%	41%	100%
Mean age	35,6	33,7	34,8
Population 20+	145000	92000	237000
Population 40+	66000	41000	107000
Population 50+	34000	21000	55000

Figure 1 Estimated EU+ (EFTA) country mobile population

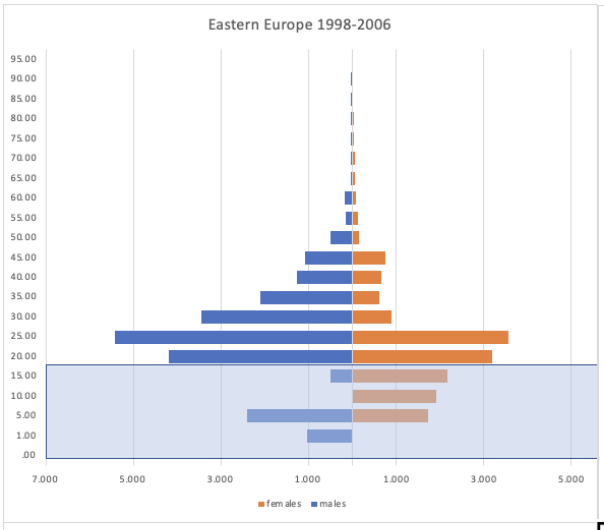


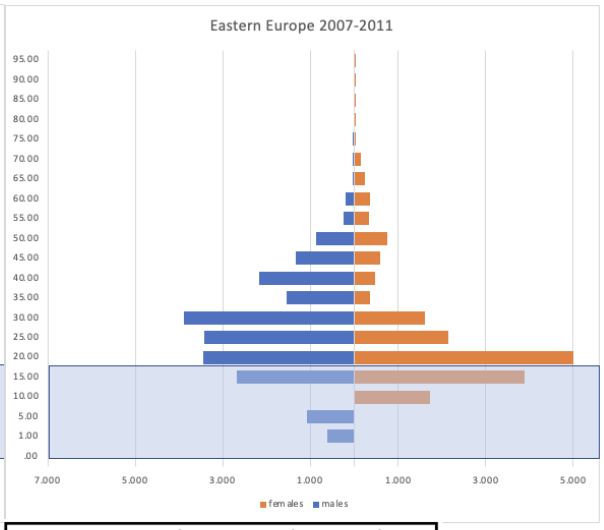


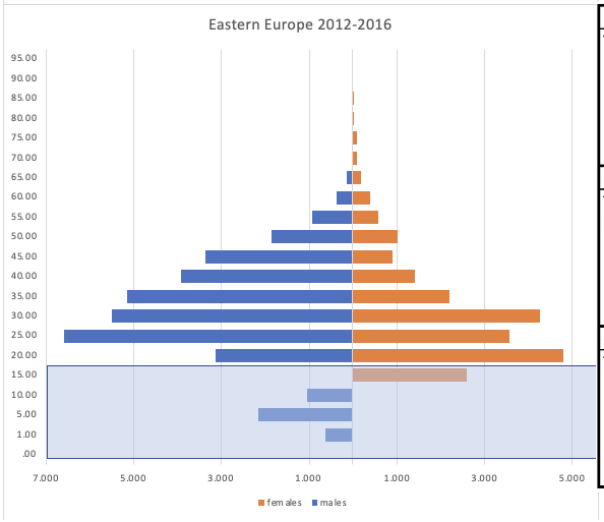


1998-2006	Male	Female	Total
Total population	109000	93000	202000
Gender %	54%	46%	100%
Mean age	25,9	24,9	25,4
Population 20+	75000	54000	129000
Population 40+	15000	14000	28000
Population 50+	4000	5000	10000
2007-2011	**Male**	**Female**	**Total**
Total population	101000	66000	166000
Gender %	61%	39%	100%
Mean age	26,4	28,2	27,1
Population 20+	68000	41000	110000
Population 40+	16000	16000	32000
Population 50+	5000	7000	12000
2012-2016	**Male**	**Female**	**Total**
Total population	113000	82000	195000
Gender %	58%	42%	100%
Mean age	31,0	32,7	31,7
Population 20+	90000	70000	161000
Population 40+	28000	23000	51000
Population 50+	9000	9000	18000

Figure 2 Estimated non- EU (third) country mobile population

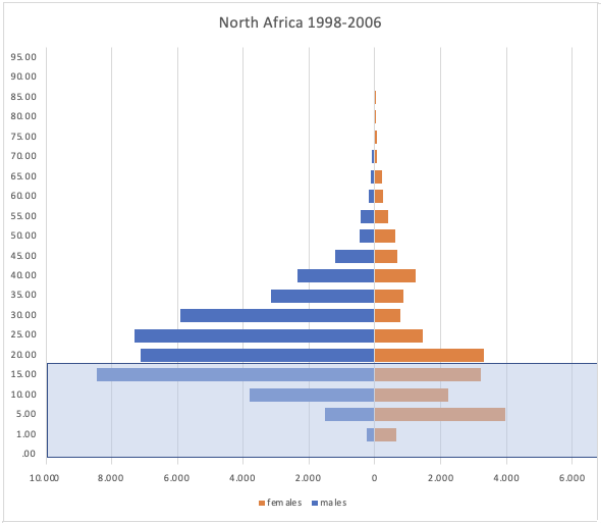


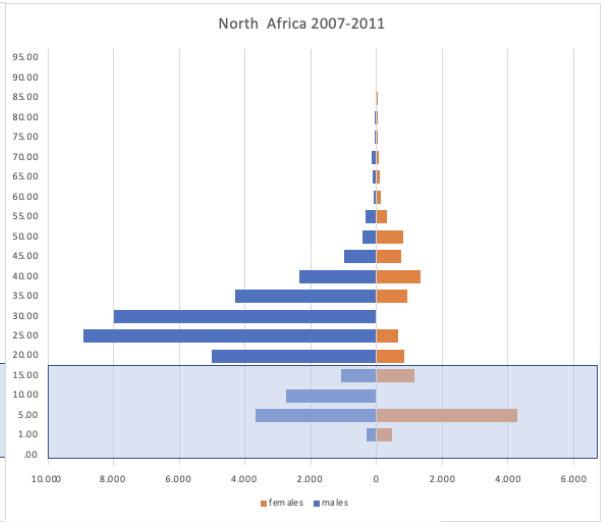


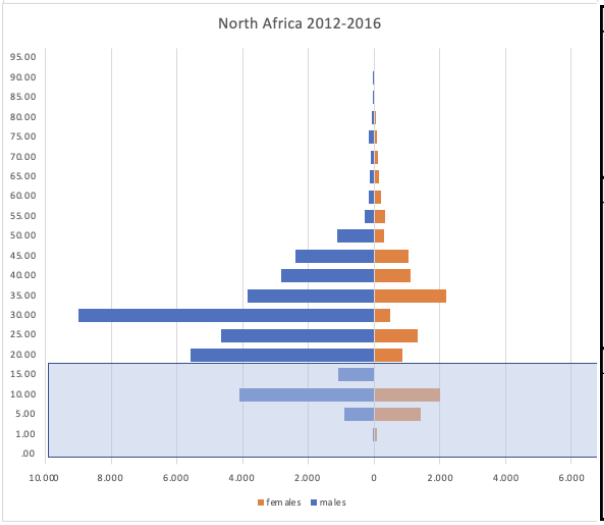


1998-2006	Male	Female	Total
Total population	22000	16000	38000
Gender %	58%	42%	100%
Mean age	27,9	24,7	26,6
Population 20+	18000	10000	29000
Population 40+	3000	2000	5000
Population 50+	1000	1000	2000
2007-2011	**Male**	**Female**	**Total**
Total population	22000	18000	40000
Gender %	54%	46%	100%
Mean age	30,1	27,4	28,9
Population 20+	17000	13000	30000
Population 40+	5000	3000	8000
Population 50+	1000	2000	3000
2012-2016	**Male**	**Female**	**Total**
Total population	35000	22000	57000
Gender %	61%	39%	100%
Mean age	33,6	32,3	33,1
Population 20+	31000	20000	51000
Population 40+	11000	5000	15000
Population 50+	3000	2000	6000

Figure 3 Estimated Eastern European mobile population

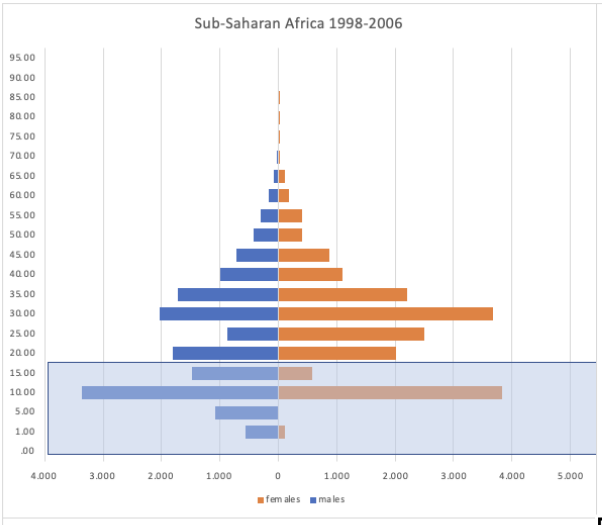


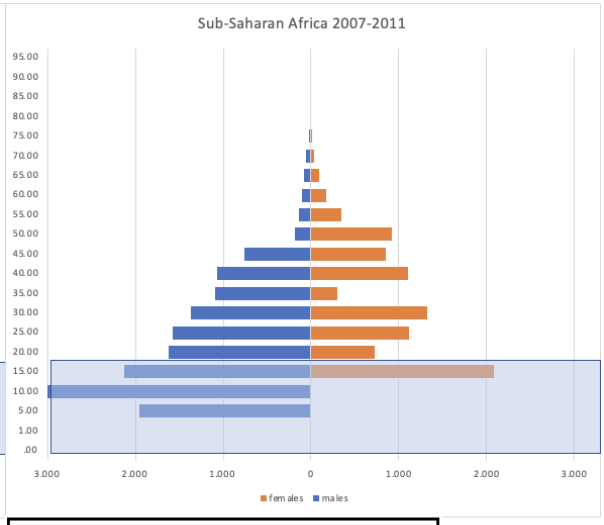


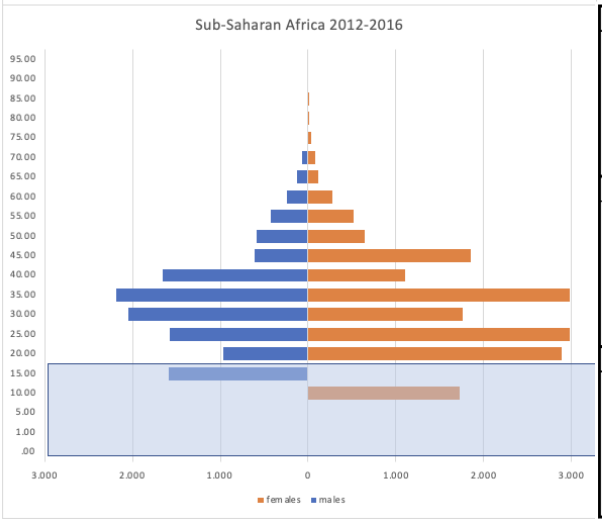


1998-2006	Male	Female	Total
Total population	43000	20000	63000
Gender %	68%	32%	100%
Mean age	26,3	23,5	25,4
Population 20+	28000	10000	38000
Population 40+	5000	4000	9000
Population 50+	1000	2000	3000
2007-2011	**Male**	**Female**	**Total**
Total population	39000	12000	51000
Gender %	76%	24%	100%
Mean age	28,0	25,5	27,4
Population 20+	31000	6000	37000
Population 40+	5000	4000	8000
Population 50+	1000	2000	3000
2012-2016	**Male**	**Female**	**Total**
Total population	37000	12000	48000
Gender %	76%	24%	100%
Mean age	30,8	30,9	30,8
Population 20+	30000	8000	39000
Population 40+	7000	3000	11000
Population 50+	2000	1000	3000

Figure 4 Estimated North African mobile population







1998-2006	Male	Female	Total
Total population	16000	18000	34000
Gender %	46%	54%	100%
Mean age	26,0	29,3	27,8
Population 20+	9000	14000	23000
Population 40+	3000	3000	6000
Population 50+	1000	1000	2000
2007-2011	**Male**	**Female**	**Total**
Total population	17000	9000	26000
Gender %	65%	35%	100%
Mean age	23,5	34,6	27,4
Population 20+	8000	7000	15000
Population 40+	2000	4000	6000
Population 50+	1000	2000	2000
2012-2016	**Male**	**Female**	**Total**
Total population	12000	17000	30000
Gender %	41%	59%	100%
Mean age	35,3	33,5	34,2
Population 20+	11000	16000	26000
Population 40+	4000	5000	8000
Population 50+	1000	2000	3000

Figure 5: Estimated Sub-Saharan African mobile population

5. DISCUSSION

In this study, irregular migrant population stocks were estimated using an unconventional method. Instead of direct observation, the method relied on mortality extrapolation to estimate the total stock of internationally mobile citizens, regardless of their residential status. This stock was estimated at nearly half a million individuals in 2016, on top of Belgium's official population of 11.3 million at the time. Mortality extrapolation is based on the predictability of mortality patterns when population composition (age, gender, and origin) is known. In this case, however, the population was inferred from mortality data rather than mortality being predicted from the population size.

Once the total mobile population was estimated, the next challenge was to isolate the irregular migrant population. By subtracting the number of regular-status mobile citizens (e.g., tourists, visa-holders, asylum seekers) from the total, we arrived at an estimate of the irregular population. Out of the 490,000 mobile foreigners in Belgium around 2016, 329,000 were identified as not having confirmed regular status, meaning that they are either undocumented or have overstayed the validity of their status (e.g. the 3 months benchmark after which registration of mobile EU-citizens is mandatory). The majority of these—217,000 individuals—were EU+(EFTA) citizens, mostly from neighbouring countries. The remaining 112,000 were third-country nationals, not covered by diplomatic status, visas, or asylum procedures. This 112,000 number is the final estimate of Belgium's irregular migrant population around the year 2016. This estimate is quite a bit lower than numbers around 150,000 previously cited in the media (Caritas International, 2019), but for which the methodological basis was missing.

KEY ADVANTAGES

The main advantage of mortality extrapolation lies in its reliance on a universally observed event—death—as the primary indicator. Mortality is objectively recorded and offers a stable basis for extrapolation through demographic life tables. This method is in sharp contrast to other techniques that depend on selective and partial observations, such as arrests or border crossings, where extrapolation factors are often speculative or inadequately calculated.

Another advantage is the level of demographic detail that mortality extrapolation provides. The method allows for population estimates to be broken down by age group and gender, offering greater insights into the population structure. This demographic specificity is a key strength, enabling more precise comparisons across time and space. In Belgium, for example, the method effectively captured the outcomes of the 2009–2011 regularisation wave, demonstrating a significant reduction in non-registered children and also in the age group of their parents. A reverse effect was captured in later years, when the lack of new regularisation opportunities after that wave ended caused an increase in older non-registered citizens. The potential of taking clear pictures of irregular migrant population

dynamics before and after regularisation measures offer unique insights into short and long-term policy effects.

However, while the method is highly effective in the first step in the estimation process (estimating the total stock of mobile citizens), it is less precise when applied to the irregular population. The challenge lies in the availability and quality of data for regular-status individuals, particularly EU+(EFTA) citizens, whose free movement rights do not generate the same administrative trail as non-EU nationals. This limits the demographic clarity when trying to isolate irregular migrants within the broader non-registered population, as regular and irregular subpopulations may have different demographic profiles.

RELIABILITY

For successful application, the method's vulnerabilities must be addressed, especially in terms of data reliability. The key challenge lies in the sample size of deaths among mobile citizens. Consistent population estimates were only achieved when deaths were aggregated over periods of five years and in country groups of at least 15,000 to 20,000 individuals. The analysis reaches best stability when the group size reaches 40,000 to 50,000 individuals. However, for certain subgroups—particularly children, where mortality rates are very low—the estimates can remain unstable even with large data aggregates.

We repeated mortality extrapolation for three periods. Outcomes were quite consistent over time. This can be observed in the tables annexed to the figures. Moreover, as mentioned before, differences over time could convincingly be attributed to changes in policy.

ASSUMPTIONS

The main methodological assumption is that mortality risks for irregular migrants are similar to those of recently arrived legal immigrants from the same countries of origin. While this assumption is supported by the healthy migrant paradox—the phenomenon where migrant populations often exhibit lower mortality rates than expected given their socio-economic status—it remains largely untested for non-registered individuals. Irregular migrants may face additional health risks due to poor working conditions or limited access to healthcare. The uncertainty about possibly higher mortality risks could ultimately lead to some degree of overestimation of the unregistered and irregular population.

SCALABILITY

From a methodological standpoint, mortality extrapolation is well-suited for application in other national and temporal contexts. The key requirement is the availability of complete mortality data including mobile populations, and a population registry system that allows post-mortem distinction between deaths in registered and unregistered populations. Such complete mortality data is widely available across EU countries and beyond. Most countries maintain exhaustive Cause of Death (COD) statistics, which can be used for similar analyses. In Belgium, for example, COD data is linked to the national population register, allowing for the identification of non-registered deaths. This method can be replicated in other countries with similar data structures, though the operationalisation of this data requires cooperation between statistical agencies, population registries, and sometimes foreign affairs offices. It must however be considered that population registration systems differ across Europe and worldwide. Belgium, The Netherlands, Austria and Scandinavian countries typically have centralized population registers that can be linked to demographic events such as death or

migration, and that permit individual level follow-up over time. Some countries have decentralized population registration systems, or even lack such a system entirely (Portugal, U.S.). Still others (Spain) include irregular residents in their population registers making it very difficult to make the crucial post-mortem distinction between mortality of regular and irregular residents.

The availability of "donor" mortality data—data on mortality risks for similar populations—also facilitates the application of this method in other countries. Such data often show lower-than-expected mortality rates, reflecting the immigrant mortality advantage or unobserved return migration of ill migrants. These factors may cause some deviation between donor population mortality profiles and those of irregular migrants, but this does not severely compromise the method's overall validity.

The final stage of the process relies on the availability of detailed data on regular mobile populations. The composition of these populations varies greatly between countries, depending on the prevalence of posted workers, diplomats, students, tourists, and asylum seekers. While much of this mobility is governed by Schengen rules, the availability and detail of data on these groups can vary, posing potential challenges for applying the method in different contexts.

ETHICS

There are several ethical dimensions to consider in research involving minority and vulnerable populations. Legally, the focus is on protecting the privacy of living individuals, meaning that using mortality data—which relates to deceased persons—does not violate privacy rights. However, this minimal interpretation overlooks the sensitive nature of mortality data and its potential implications for the dignity of the deceased.

The aim of this research is to provide a detailed understanding of minority populations, and the study was conducted in accordance with Responsible Research and Innovation (RRI) ethical standards (Cyrus, 2023). The method is designed to minimise risks for the populations under study. The results are not published at small geographical scales, and no very small groups are identified. Moreover, the analysis avoids digital surveillance techniques, relying only on non-digital observation to respect privacy and mitigate potential harms.

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ANNEX 1

The MIrreM Methods Lab conducted a review of 21 traditional and innovative methodological approaches for estimating irregular migrant stocks and flows. Each approach was assessed based on its core concept, data sources, definition and coverage of irregular migration, estimation assumptions, reliability, scalability, general assumptions, and ethical considerations.

Building on this review, we developed six innovative approaches that have the potential to advance research on irregular migration.

As part of the broader MIrreM project, the WP6 Methods Innovation Lab carried out the following six Pilot Studies (PS). Please find the MIrreM Briefing Papers about the other Pilot Studies linked below:

MIrreM Briefing Papers	Authors	DOI
PS1 - Exploring the use of aggregate air passenger data for estimating overstayer inflows	Luca Bernasconi Ettore Recchi	https://doi.org/10.5281/zenodo.14809013
PS2 - Measuring the participation of irregular migrants in the informal economy	Aslı Salihoğlu Carlos Vargas-Silva	https://doi.org/10.5281/zenodo.14809000
PS3 - Estimating irregular migrant stocks using social media data and machine learning	Alejandra Rodríguez-Sánchez Jasper Tjaden	https://doi.org/10.5281/zenodo.14808984
PS4 - Irregular migration: What can mortality reveal?	Johan Surkyn Tuba Bircan	https://doi.org/10.5281/zenodo.14808979
PS5 - Estimating irregular migration in the UK using a health care reform	Alejandra Rodríguez-Sánchez Jasper Tjaden	https://doi.org/10.5281/zenodo.14808948
PS6 - Measuring irregular migration stocks through social media surveys	Jasper Tjaden Alejandra Rodríguez-Sánchez	https://doi.org/10.5281/zenodo.14801999

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