

A new methodological framework for calculating population projections

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1. Introduction

The National Statistics Office (NSO) has developed a new methodological framework for calculating population projections. While this is not the first time the NSO is producing population projections, previous estimates were developed at a time of population stability, characterised by slower population growth and lower migration rates. Demographic changes over the past 10 years have been more pronounced, with the highest estimates of net migration being recorded in the past few years and consistent declines in the fertility rate. In this changing demographic context, a new robust methodology was needed. This statistical insight describes the method and presents the first population projections estimated with this new approach.

2. Background

Population projections are estimates of how a population is likely to change in the future. They are produced using current data on births, deaths, and migration, along with assumptions about how these factors might evolve in the future. In essence, the projection is a “what-if” scenario, where future targets for demographic inputs are set and the population is calculated to show how it would evolve over time, if these targets are met. Population projections therefore carry uncertainty because they are based on assumptions set in the present about future trends in fertility rates, life expectancy, and migration. Changes in policies, economic crises, or other major events, such as a pandemic, natural disaster or war, can significantly alter demographic trends. Even small deviations in assumptions can lead to different long-term projection outcomes. Population projections should therefore be interpreted with caution, as they are estimates, rather than certainties. They are best seen as a guide rather than precise predictions. Nevertheless, population projections are widely used to plan for future demands in areas like healthcare, education, housing and transport. They are also important to inform long-term policy decisions in areas such as pensions, sustainability and resource management.

3. Method

This section will describe the methodology used to produce the population projections. Additional methodological notes, including concepts and definitions, are available in a latter section. The population projections were estimated using the three components of population change – fertility,

mortality and migration. Models for projecting the three components were developed separately, with future targets assigned for each. The three components were then applied to the base population, which, in this analysis, was as at end of year 2024. The final projected population was estimated using the cohort-component method. Apart from the estimation of a baseline scenario, sensitivity analysis was conducted for four alternative scenarios.

The first projection year is 2025, with a projection horizon of 55 years, meaning the last projected year is 2080. Estimates of the three components of population change were produced separately for the Maltese and foreign resident populations, which allowed for the subsequent projected population to be produced for the Maltese, foreign and total resident populations, respectively. The projected population was estimated for each single year of age, up to 100+ and for males and females. Several demographic indicators were also estimated for each projected year from the baseline scenario. The estimation methods and assumptions for each component will be presented separately. All analysis was conducted in R version 4.2.2 (2022-10-31 ucrt).

3.1 Fertility

The total fertility rate (TFR) is a summary measure of fertility that estimates the average number of babies born to a woman over her lifetime if she experienced current age-specific fertility rates (ASFRs). The ASFRs estimate the rate of birth in each age band, while the TFR is the sum of these rates. Having an estimate of the ASFRs for a population allows for the estimation of expected number of births for that specific population and is an essential component to produce a population projection. Two processes were developed for the fertility component of this projection exercise – (1) projection of future TFR; and (2) projection of future fertility patterns across single years of age (ASFRs) that correspond to the projected TFR.

The fertility component was estimated separately for Maltese and foreign residents to consider variations in fertility patterns across the two groups. The input time series used was from 2012 to 2024. This time series was selected because fertility rates by citizenship of mother were available from 2012, and it is expected that future fertility rates are more likely to be influenced by current trends rather than past trends. To predict the future evolution of fertility, a target value for TFR and convergence point (year when this ultimate value is to be reached) were required. The expected future TFR in the baseline scenario was set to the average value of the five countries in the European Union (EU) currently with the highest TFR values. At the time of analysis, the most recent estimates available were for 2023. The five top performing countries were Bulgaria (1.81), France (1.66), Hungary (1.55), Romania (1.54) and Slovenia (1.51) which average out to a value of 1.62. Malta currently has the lowest TFR value within the EU at 1.01 in 2024 and this has been declining annually since 2016. Despite this, for the purposes of this analysis, it is assumed that in the distant future the fertility rate will recover. This is primarily because:

- Current high migration patterns are expected to slow down which would in turn lead to a slowing down in the growth of the base population. If the annual number of births in the population were to stay the same, the TFR would be expected to statistically increase as the growth of the base population used to estimate the TFR would slow down.

- Demographic theory assumes that fertility rates eventually stabilise after a period of transition as it is assumed that a consistent decline or increase in fertility rates would not be indefinite. This ensures that in the very long term, the projections remain plausible.

To account for the fact that the TFR in the base year 2024 is comparatively low against the target set, and TFR values have been declining annually, the following assumptions were made to ensure the projected increases are plausible:

- The value of 1.62 is to be reached in 2130, i.e. 50 years after the end of the projection horizon.
- For the first three years of the projection, i.e. 2025 – 2027, the value of the TFR will be set as the value of 2024, i.e. it will remain constant. TFR will begin to increase linearly from 2028 to the convergence value in 2130.

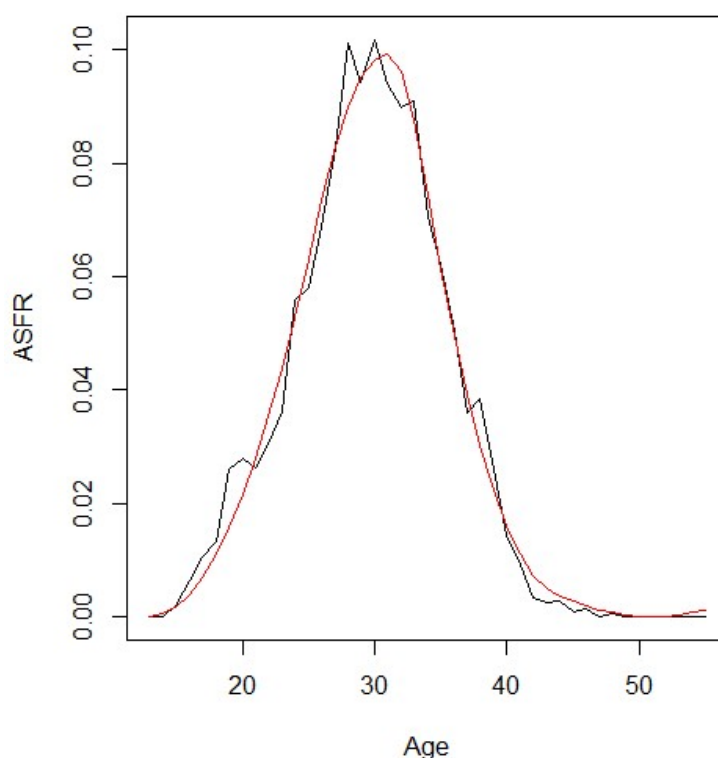
Future fertility patterns, in terms of the ASFRs, were projected using the Schmertmann model (Schmertmann, 2003). This model is a well-established method and is widely used in demographic projections as it is considered flexible and generally easy to interpret. The Schmertmann model uses past ASFRs to project future ASFRs through the application of a quadratic spline function that represents fertility as a curve, with three parameters estimated to best fit the data:

<i>P</i>	The age at which fertility reaches its peak or maximum level in the population in that year.
<i>H</i>	The age at which fertility is at the level of half the peak (<i>P</i>) and indicates how spread out or compressed the fertility schedule is around the peak age.
<i>R</i>	The scaling parameter that adjusts the overall level of fertility rates in the age-specific fertility schedule. <i>R</i> controls the height of the fertility curve without changing its shape.

The parameters *P* and *H* are used to fix the shape of the curve, while *R* is used to scale the curve up or down, in a proportional manner, to match the ASFRs required to reach the total fertility rate (TFR) observed in the present or expected in the future. Another parameter in the model is alpha, which marks the age at which fertility begins to be observed in the population. Unlike the other parameters, this is not generally predicted and is set to a constant value to reflect the typical biological and social onset of fertility.

Current age-specific fertility rates were fit to the model to estimate the *P* and *H* parameters for each year. Figure 1 shows an example of actual ASFRs fit to the Schmertmann model to extract the corresponding *P* and *H* values. The red curve represents the fitted values emerging from the model, while the black curve is a plot of the actual ASFR values.

Figure 1: Actual age-specific fertility rates (black line) and predicted age-specific fertility rates (red line) from the model for Maltese resident mothers by age of mother at birth: 2014



An AutoRegressive Integrated Moving Average (ARIMA) model was used to predict future values of P and H using the data extracted from fitting the available time series of ASFRs from 2012 to 2024 for Maltese and foreigner resident mothers separately. ARIMA models are widely used to understand patterns in a data time series and to predict future values of the series. Having the projected P and H values, as well as the projected TFRs, the Schmertmann model could be used to estimate the ASFRs for each projected year. The value of alpha was set to the constant value of 13, to reflect the youngest age at which mothers were observed to give birth in the actual time series. The projected ASFRs were then used in the composition of the future population, using the cohort-component method, which will be described in another section.

3.2 Mortality

Life expectancy (LE) is an average measure of expected remaining years of life in a population and is estimated using life tables, which incorporate age-specific mortality rates (ASMRs) derived from data on deaths and population counts. The most common measure of life expectancy is that at birth. This estimates, for a given year, the average number of years a newborn is expected to live. Having an estimate of the ASMRs for a population allows for the estimation of expected number of deaths for that specific population and is an essential component to produce a population projection. To produce

the projection, two processes were developed for the mortality component– (1) projection of future LE; and (2) projection of future ASMRs that correspond to the projected future LE.

Unlike the fertility component, the mortality component was estimated for the total resident population rather than for Maltese and foreigner resident populations separately. Most deaths occur among the population aged 75 and over. The growth of the foreign resident population occurred mainly in the last 10 years, meaning that the current foreign resident cohort is young, thus experiencing low mortality rates. Estimating ASMRs using small mortality counts leads to large variability and volatility in terms of trend. Using these ASMRs as input for the modelling techniques required for the projection would lead to challenges in terms of model fit and potentially unreliable estimates for the foreign resident population. Therefore, a decision was taken to work at the total level, with the resulting ASMRs applied to both the Maltese and foreign resident population projections. A timeseries of ASMRs for the total resident population from 2012 to 2024 was used for the analysis.

To predict the future evolution of mortality, target values for male and female LE and a convergence point, were required. Malta currently has one of the highest life expectancies at birth for both males and females in the EU. A person born in 2024 can expect, on average, to live to the age of 83.0, for females this stands at 84.8 while for males it stands at 81.2. For the baseline scenario, a target of 89.5 was set for females and 85.9 for males to be reached at the convergence point in 2130. The projected values of LE were assumed to increase linearly from the base value to the target value at the convergence point. These targets were set assuming that, while life expectancy is expected to continue to increase, it may be at a slower pace considering the current values are already high. Conservative targets were also set considering the yet unknown potential impact of the foreign resident population on mortality patterns should they continue to age in Malta.

Future mortality patterns up to age 100+, in terms of the ASMRs for males and females, were predicted using the Lee-Carter model (Lee & Carter, 1992). Like the Schmertmann model, this is a widely used method for the projection of mortality patterns and is applied often in population projections. The Lee-Carter model is a log-linear model. The log ensures proportional changes in mortality are modelled linearly and keeps forecasts realistic. The method models the logarithm of age-specific mortality rates using three components:

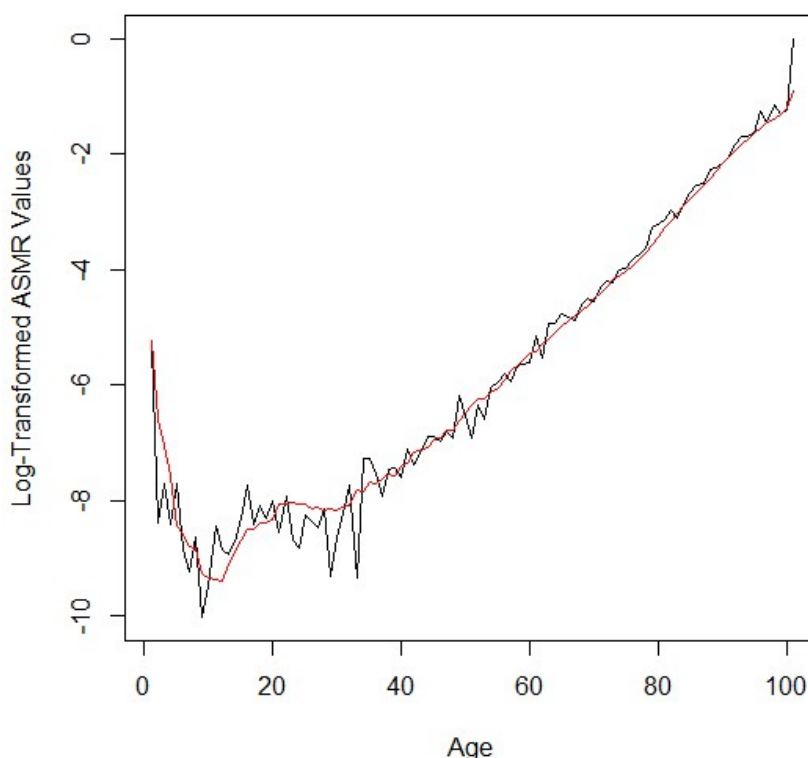
- | | |
|------------------------|--|
| a_x where $x=1....N$ | An age-specific component that represents the average mortality rate at each age over time. |
| k_t where $t=1....T$ | A time-varying mortality index that captures the overall level of mortality in a given year and summarizes mortality trends across all ages. |
| b_x where $x=1....N$ | An age-specific sensitivity that reflects how mortality changes at each age in response to changes in the mortality index (k_t) over time. |

Since the model works with logarithms, the input ASMRs required some data preparation before they could be used in the analysis. The following steps were taken:

- Due to small death counts, certain ages had 0 deaths leading to an ASMR of 0. An absolute value of 0 cannot be converted onto the logarithmic scale, therefore these were replaced with a value very close to 0. This was done by either replacing the absolute 0 value to the average value of ASMRs close to zero from neighbouring age groups or, if this was not possible, replacing the 0 with 1×10^{-76}
- Converting the mortality rates to probabilities of dying using Chiang's formula (Chiang, 1978). This restricts the mortality data in the model to values ranging from 0 to 1 thus avoiding potential instability at older ages where mortality may be very high. It also allows data to be compatible for eventual construction of the life table and estimation of life expectancy.
- Applying a log-transformation to the probabilities of dying.

Once the data transformation was complete, it was fit to the model to extract values for each of the component's a_x , k_t and b_x . The moving-average method was applied to smooth the fitted data emerging from the model. Figure 2 presents an example of the log-probabilities of dying applied to the model. The red line represents the fitted smoothed values emerging from the model, while the black line is a plot of the actual log probabilities of dying by age.

Figure 2: Log-transformed actual probabilities of dying (black line) and smoothed predicted log-probabilities of dying from the model (red line) by single years of age: 2024



The aim was now to project probabilities of dying that align with the projected estimates of life expectancy at birth using the input data extracted from the model fits. This was achieved by keeping the components a_x and b_x constant and predicting values of k_t that led to the probabilities required to estimate the predicted life expectancies. A random-walk with drift model was used to predict future values of k_t using the input time series. This is a stochastic process and is deemed an appropriate method to predict the mortality index since it accounts for the downward trend seen in mortality, while also considering the potential impact of year-to-year randomness brought about by unpredictable events.

An iterative process was implemented to find the best predicted values for k_t to match the projected life expectancies. For each iteration, the life table was computed using the log probabilities of dying estimated with the constant a_x and b_x parameters and the predicted k_t values until the resulting life expectancy at birth aligned to the target value. The final values of k_t , along with the a_x and b_x parameters, were used to produce the ASMRs for each projection year that aligned with the projected life expectancies. Since these were on the log scale, they were first transformed back into the original scale through an exponential function before being used in the cohort-component model.

3.3 Migration

Predicting migration is the most challenging of the three components of a population projection due to the complex and unpredictable nature of migration flows. Migration is heavily influenced by policies within the receiving and sending countries as changes in the political, economic, and social situation of a country may be push or pull factors for migration. Unforeseeable events such as wars and geopolitical instability may also cause mass migration events to occur. Considering this complexity and uncertainty, the approach taken to project migration was kept as simple as possible to avoid using complex models which are less adaptable to change.

Given the difference in migration patterns for foreign and Maltese citizens, the migration projection was conducted separately for the two groups. The projection requires (1) future values of net migration measured through immigration and emigration, (2) the share of each component attributed to males and females and (3) the age distribution of these flows. Three processes were set up to estimate these three elements of the migration projection.

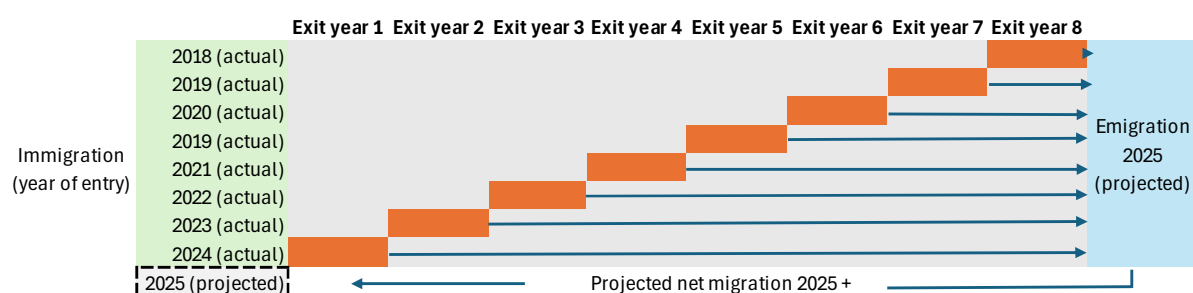
Estimates of Maltese migration patterns have generally been constant over the period 2012-2024, with positive, but low net migration values each year. For the future trends in the baseline scenario, an assumption was taken that the net migration for Maltese citizens would remain consistent with the past trend. The average immigration and emigration values for the period 2012 – 2024 was estimated and these were used as a constant value along the projection horizon. Immigration was set to 1,918, while emigration was set to 1,747, for an annual net migration value of 171.

Between 2012 and 2023, net migration of foreign citizens increased nearly annually, with only a significant dip occurring in 2020, attributable to the COVID pandemic. In 2024, however, a slowdown in the net migration of foreign citizens was recorded, with a net migration figure that was approximately half the value of the previous year. Considering the slow down observed in 2024 and demographic principles of expected equilibrium in migration in the long term, the following assumptions were set in the baseline scenario for foreign migration:

- Short term target of 10,000 net migrants in 2026.
- Linear decline in net migration from 2027 onwards, converging to a net migration value of 0 in 2130.

Setting a net migration value of 0 at the convergence point is common practice when projecting long term migration trends. This assumes that in the very long term, equilibrium will be reached, by which the same amount of people leaving the country will be the same as the amount entering. This also sets a simple and stable reference point for the future outside the projection horizon, considering the difficulty of projecting migration in the very long term due to uncertainty. Once total estimates for foreign net migration along the projection horizon were estimated, these needed to be split into the immigration and emigration components. The estimation of emigration was based on the concept of exit rates. Administrative data on residence permits was used to estimate the share of persons leaving the country each consecutive year after their year of entry. These estimates were calculated for persons entering from 2013 to 2023, and an average exit rate for each exit year, up to the eighth year, from entry was taken. An iterative process was applied, using the exit rates and the immigration figures for each of the eight years prior to the reference year. By applying exit rates to the immigration values by year of entry relative to year of exit, expected emigration counts were estimated. These were summed to extract the total emigration estimate for the reference year. This emigration estimate was then used to estimate the immigration by adding it to the net migration figure projected for the year. This process was repeated for each year of the projection horizon. Figure 3 describes how the procedure was implemented using 2025 as an example:

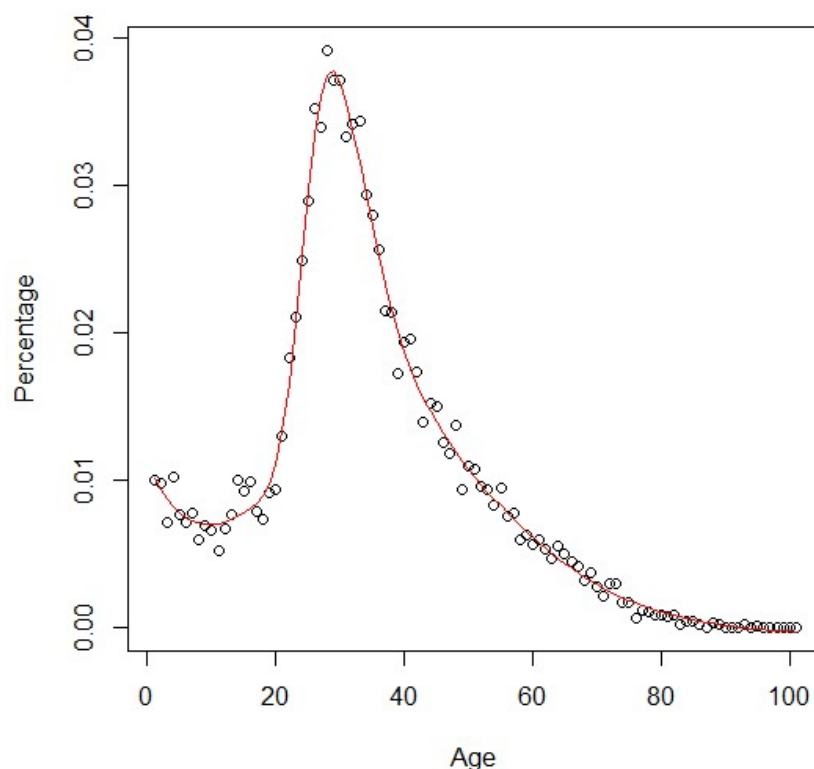
Figure 3: Method used to predict emigration and immigration counts for foreign citizens based on exit rates using year 2025 as an example.



Once estimates of immigration and emigration for Maltese and foreign citizens were produced, the ratio of males and females needed to be established. Currently the majority share of immigrants and emigrants are male - approximately 70 per cent. Long term projections tend to assume that the sex imbalance will eventually even out by the convergence point, based on the principle that migration flows stabilise because of the economic, social and family processes that drive migration. It was therefore assumed that the current 70/30 sex ratio would converge linearly to a 50/50 ratio by 2130. These projected proportions were applied to the estimated immigration and emigration counts to subdivide them by sex.

The final step was to distribute the immigration, and emigration counts, now subdivided by sex, across age. To do this, the Castro-Rogers method was used (Rogers & Castro, 1984) to model and smooth historical age distributions of migration. This is a flexible, multi-parameter exponential model that mathematically represents migration rates by age, capturing the key peaks and troughs typically observed in migration behaviour over the lifespan. The input data used was from 2015 to 2024. This time series was chosen since migration patterns changed considerably in the past decade when compared to previous years. Recent migration patterns are expected to better predict future trends in terms of age structure. The age distributions, as proportions adding up to 1, for the immigration and emigration data from 2015 to 2024 were produced for each year by sex, and for the Maltese and foreign data separately. Each distribution was fit using the Castro-Rogers model. An example is shown in figure 4. The points on the curve represent the actual proportions for each age, while the red curve is the fitted data emerging from the model:

Figure 4: Actual age distribution of male foreign immigration (black points) and predicted age distribution of male foreign immigration (red line) by age from the model: 2015



Visual assessment of the curves showed that over the period, the age distributions were relatively constant for both immigration and emigration. Seeing the consistency with time, the smoothed proportions for the migration components were used to produce an average distribution by age separately for both citizenship groups by sex. This distribution was used to distribute the migration data counts by age for each projected year across the horizon. The age distribution was kept constant

when considering the consistency of the age structure in the historical data. This therefore does not consider any future changes in the age structure of migration flows, such as, a potential increase in out migration in older age groups. The final immigration and emigration count by citizenship, age and sex were then used in the cohort-component model to produce the projection.

Table 1 provides a summary of the assumptions applied to each component in the baseline scenario:

Table 1: Assumptions for the baseline scenario

Component	Assumption	Convergence point
Fertility	Maltese residents: constant value of base year TFR 1.12 (2024) for years 2025 – 2027, linear interpolation to convergence point value of 1.62	2130
	Foreign residents: constant value of base year TFR 0.97 (2024) for years 2025 – 2027, linear interpolation from 2028 to convergence point value of 1.62	
Mortality	Males: linear interpolation of life expectancy to convergence point value of 85.9	
	Females: linear interpolation of life expectancy to convergence point value of 89.5	
Migration	Sex ratio: Male/Female ratio of 70/30 converges to 50/50	
	Maltese residents: constant net migration value of 171, based on an immigration value of 1,918 and emigration value of 1,747	
	Foreign residents: target of 10,000 net migrants in 2026, converge to net 0 migration from 2027. Emigration figures calculated using exit rates, immigration calculated by summing projected emigration and projected net migration.	

3.4 Cohort-component model

The cohort-component method is one of the most widely used techniques for producing population projections. It projects the size and structure of a population into the future by age, sex, and time, using the components described above, applied to an initial base population. The process is repeated on each new population stock that has been compiled until the projection horizon is reached. Since there are variations in the components for males and females, the procedure is estimated separately for the two. Since components were also produced separately for the Maltese and foreign resident population, the process was further subdivided by citizenship such that separate projections were computed for the population of Maltese males, Maltese females, foreign males and foreign females. The total resident population was the addition of the four.

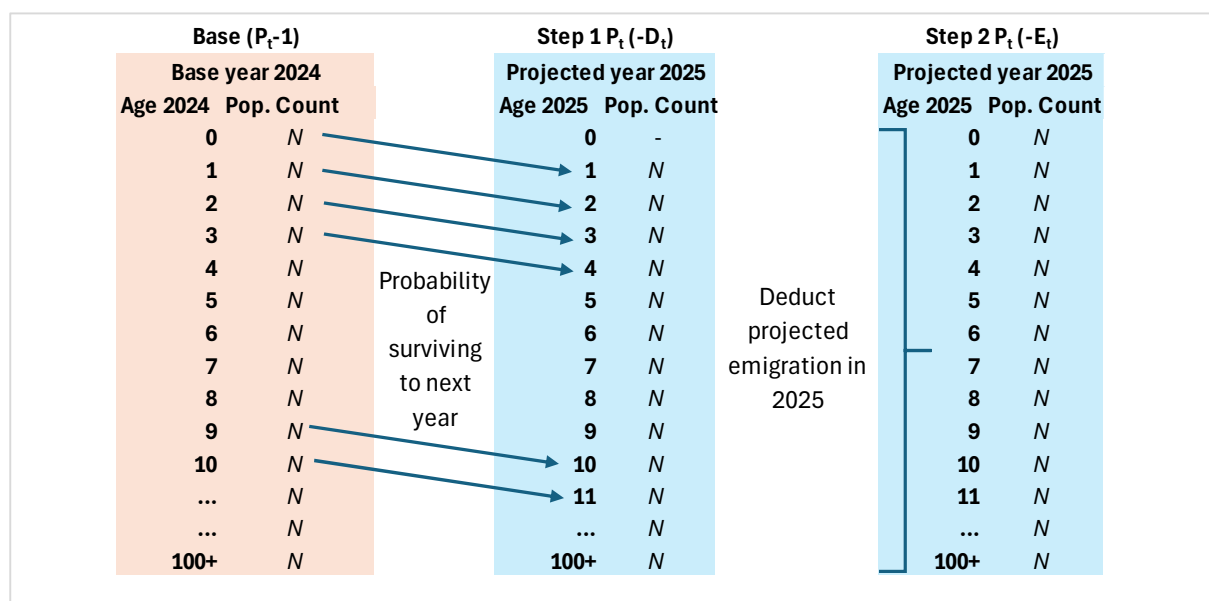
The model can be defined in terms of exits and entries into the population. The exits are deaths and emigration, while entries are births and immigration and is compiled as described below:

$$P_t = P_{t-1} + B_t - D_t + I_t - E_t$$

Where P_t is the total resident population at the end of year t (the projected year), P_{t-1} is the total resident population at the end of year $t-1$ (the base year), B_t is the total number of babies born to the resident population during year t , D_t is the total number of resident deaths occurring in the population during year t , I_t are the total number of immigrants entering the population in year t and E_t are the total number of emigrants exiting the population in year t .

The process works first on the exits since these occur before the end of the year is reached and apply to the resident population stock in the base. The first step is to estimate the number of people in the base population who survive into the next year. Using the projected ASMRs estimated previously and Chiang's formula (Chiang, 1978), a probability of surviving for each single year of age is extracted and applied to the base population. Those who survive are aged forward into the next age cohort which produces the initial population stock for the projected year from age 1 to 100+. From this stock, the emigration counts estimated for that year are deducted. Figure 5 describes the process as applied to year 2025 in the projection horizon:

Figure 5: Method applied in cohort-component model to implement exits from the population using 2025 as an example.



The next process is estimating the entries into the population in the reference year. Since the fertility rates apply to the entire resident population, including immigrants entering the population, the number of births was estimated after the immigrants were added on to the stock. The immigration counts estimated previously were added to the initial population stock after deducting deaths and emigrants. To approximate births for a specific age group, an average of the resident population of fertile women across two consecutive years (the projected year and the previous year) was taken and multiplied by the age-specific fertility rates for the projected year. This method helps smooth out potential year-to-year fluctuations in the number of females within age bands.

The estimated total births were distributed amongst males and females based on the average sex ratio exhibited in the historical birth series. Before the births were added to the population, they were subjected to the infant mortality rate estimated for the year. This is number of resident deaths of infants under one year of age as a share of the resident live births in that year. The estimated infant deaths were deducted from the number of births, and the remaining count is the age 0 value for that year. Figure 6 describes the final steps of the process:

Figure 6: Method applied in cohort-component model to implement entries into the population using 2025 as an example.

Step 4 $P_t (+I_t)$			Step 5 $P_t (+B_t)$		
Projected year 2025			Projected year 2025		
Age 2025	Pop. Count		Age 2025	Pop. Count	
0	N	Add projected immigration in 2025	0	N	Apply ASFRs to female stock (average of 2024 and 2025) by age to estimate births in 2025. Divide estimated total births using sex ratio. Apply infant mortality to deduct infant deaths
1	N		1	N	
2	N		2	N	
3	N		3	N	
4	N		4	N	
5	N		5	N	
6	N		6	N	
7	N		7	N	
8	N		8	N	
9	N		9	N	
10	N		10	N	
11	N		11	N	
...	N		...	N	
100+	N		100+	N	

Since each year several foreign residents acquire Maltese citizenship, a final step was implemented to take this into account. Based on data from 2012 to 2024, the average share of persons acquiring citizenship per year was estimated (0.8 per cent) and this was retained as a constant proportion over the projection horizon. Using the average age and sex distribution of the acquisitions adjusted by the age distribution of the projected population, a count of acquisitions by age and sex was deducted from the foreign resident population stock and added to the Maltese resident stock each projected year. Once the stocks for the Maltese and foreign resident population were compiled, the total was produced by summing them. Having projected resident population stocks, as well as projected estimates of births, deaths and migration flows, several demographic indicators were also estimated for each year.

3.5 Sensitivity analysis

Sensitivity analysis was performed to evaluate the potential impact on the projected population resulting from changes in the baseline assumptions and targets for the demographic components. This approach enabled a clear understanding of how variations in key inputs influence the overall population projection. In the alternative scenarios, only one component was changed, with the other components retaining the assumptions and targets as described for the baseline scenario. This allowed for clear isolation and understanding of the impact of the individual component on the evolution of the population. Four alternative scenarios were set as described in table 2:

Table 2: Assumptions set for the three alternative scenarios¹

Scenario	Assumption	Target
Alternative scenario 1: Low fertility	Fertility for Maltese and foreign resident populations remains constant at the value in 2024 along the entire projection horizon	MT: TFR 1.12 (constant) FOR: TFR 0.97 (constant)
Alternative scenario 2: High fertility	Fertility for Maltese and foreign resident populations converges to the highest value within the EU in 2023 (Bulgaria)	MT: TFR 1.81 (converge in 2130) FOR: TFR 1.81 (converge in 2130)
Alternative scenario 3: No migration	Immigration and emigration are 0 along the entire projection horizon (0 net migration); acquisition of citizenship among foreign residents still assumed to occur	0 immigration, 0 emigration (0 net migration)
Alternative scenario 4: No acquisition of citizenship	No acquisition of Maltese citizenship among foreign residents along the entire projection horizon.	-

¹ In the alternative scenarios, only the specified component was modified, while the remaining components retained the same assumptions and targets as those used in the baseline scenario.

4. Results

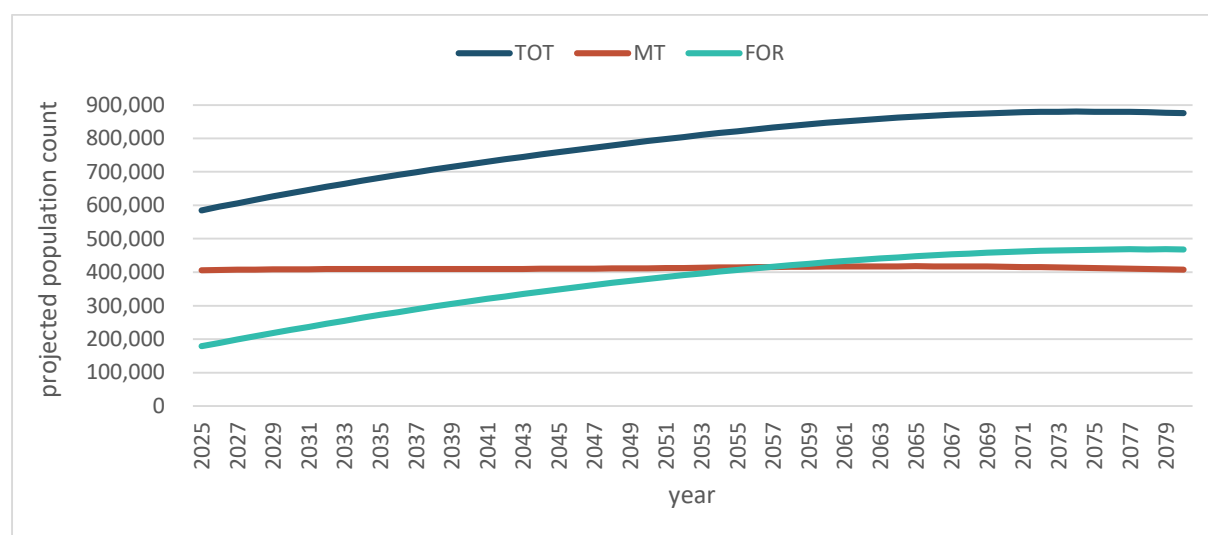
This section will present an overview of the main results of the projection exercise for the baseline scenario and sensitivity analysis. The population data should be interpreted in terms of the conditional targets set for each component as described in the previous sections.

[Detailed tables containing the projected population counts and selected demographic indicators were published as part of an online article which can be accessed here.](#)

4.1 Baseline scenario

Based on the assumptions set in the baseline scenario, the total projected resident population is expected to grow from an estimated 585,066 in 2025 to 875,529 in 2080. While the annual population growth rate is expected to remain positive until 2075, the speed at which the population grows will slow every year, until eventually, from 2076, population shrinkage will begin. Total population growth will continue to be driven by the foreign resident population, with faster growth of this population compared to the Maltese resident population continuing along the projection horizon. With low constant net migration and negative natural increase, the slight growth seen in the Maltese resident population up to 2064 is driven by the acquisition of Maltese citizenship among foreign residents. From 2065 the Maltese resident population will begin to shrink and by 2057, the share of foreigners is projected to surpass the share of Maltese (Chart 1).

Chart 1: Projected population counts from the baseline scenario for the total, Maltese and foreign resident populations: 2025 - 2080



This is predicted to occur despite higher fertility rates in the Maltese resident population, a continuous decline in migration and adjustment for acquisition of citizenship. The main reason for this is the age structure of the two populations. The foreign resident population is considerably younger. The average age of the Maltese resident population for the baseline scenario is estimated at 43.92 in 2025 - the average for the foreign resident population is nearly 10 years younger (33.95 years). This gap is expected to persist until 2040, when it will start to decline and eventually reach 4 years by 2080. An older Maltese resident population means a higher death rate, and less females of fertile age available to conceive. This leads to a lower birth rate despite higher total fertility rates. More deaths and less births result in negligible, or negative natural increase. In fact, natural increase in the Maltese resident population is expected to remain negative across the entire projection horizon, growing from -683 in 2025 to -4,503 in 2080. For the foreign resident population, natural increase is expected to remain positive until 2068, though annual declines in natural increase are projected to begin in 2041, in response to population ageing.

The population pyramids for the total projected resident populations in 2025 and 2080 visually depict the persistent aging trend expected as migration slows, life expectancy increases, and birth rates decline (Chart 2 & Chart 3).

Chart 2: Population pyramid for the total resident population from the baseline scenario: 2025

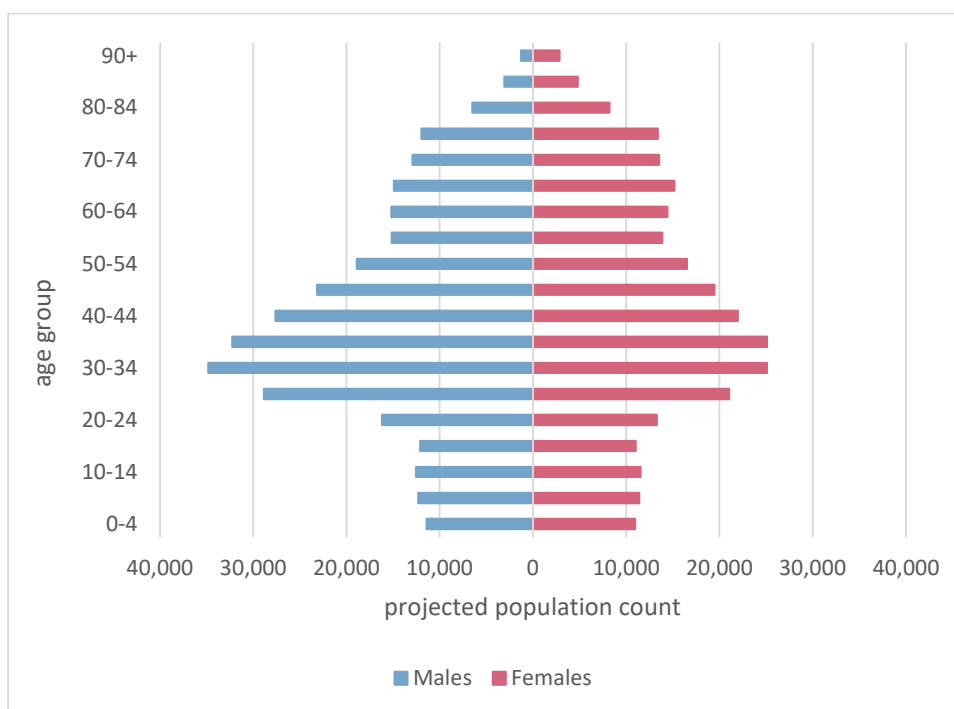
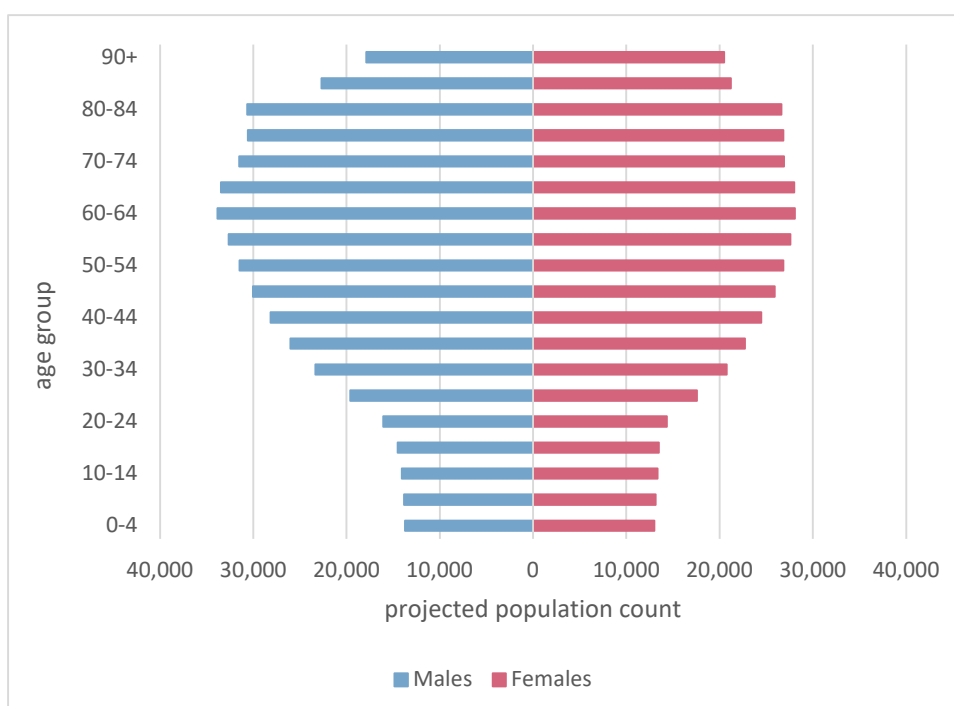
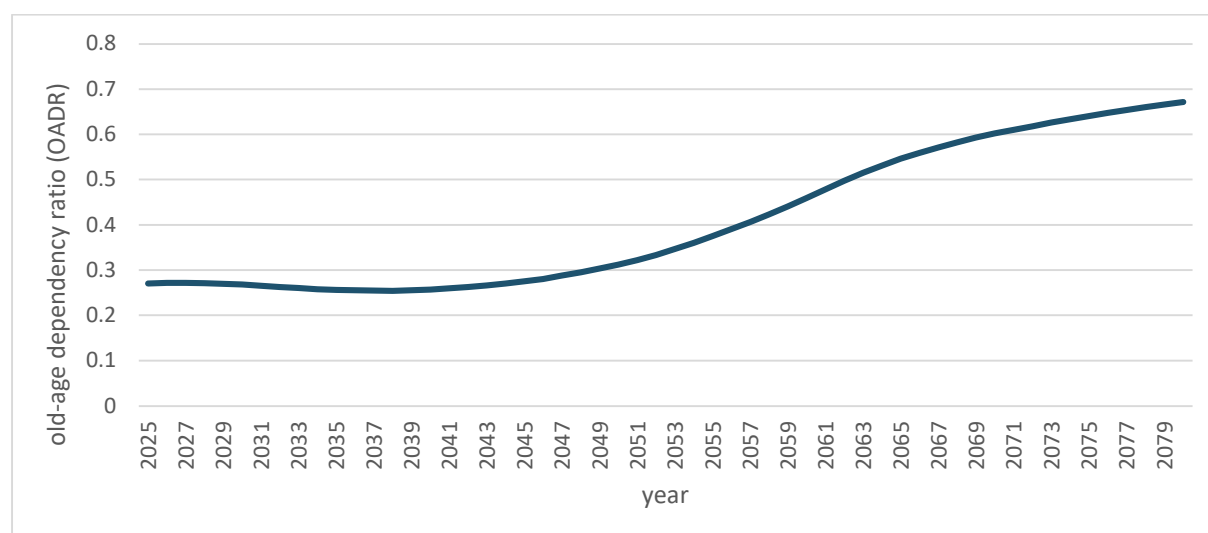


Chart 3: Population pyramid for the total resident population from the baseline scenario: 2080



The share of the total resident population aged 65 and over is set to increase from 20 per cent in 2025 to 38 per cent in 2080. In turn, both the population of children (aged below 16) and the working age population (aged 16-64) are set to decline, from 13 per cent to 10 per cent and 69 per cent to 54 per cent, respectively. The relationship between the elderly population aged 65 and over and the working-age population, aged 16-64 can be presented in terms of the old-age dependency ratio (OADR). This measure presents the ratio of persons in the population aged 65 and over to the number of persons within the working age population. A value of 1 indicates that for every person aged 65 and over there is only 1 person within the working age population. Chart 4 presents the OADR values for the total resident population across the projection horizon.

Chart 4: Old-age dependency ratios (OADRs) for the total resident population from the baseline scenario: 2025-2080



In 2025 the OADR for the total resident population is projected to be 0.27, which means for every 100 persons in the working age population there are expected to be 27 persons aged 65 and over. By 2080 this will increase to 0.67.

4.2 Sensitivity analysis

Chart 5 presents the total resident population growth for the four alternative scenarios compared to the baseline scenario. The most significant change is seen when a closed population scenario (alternative scenario 3) is assumed to occur in the future. In such a scenario, there is no migration into or out of the country and population growth is driven only by natural increase. By 2080, if no migration occurs along the duration of the projection horizon, the total resident population is expected to drop to 362,544 – a decrease of 36.9 per cent compared to the current total population count in 2024. In a scenario where there is no acquisition of citizenship (alternative scenario 4), the total population growth is nearly identical to the baseline scenario. This is because removing the process of acquisition

of citizenship mainly affects the proportion of Maltese and foreign residents within the total population but has little impact on overall population growth.

Increasing the fertility target (alternative scenario 2) leads to only a small increase in the total resident population growth, mainly in the long term when compared to the baseline scenario, with a total resident population of 893,210 in 2080 for the high fertility variation, compared to 875,529 in 2080 for the baseline scenario. On the other hand, if fertility remains constant, at the value in 2024 (alternative scenario 1), the total resident population in 2080 is expected to be 837,219, which is 38,310 less than the baseline.

Chart 5: Total resident population count from the baseline scenario and alternative scenarios: 2025-2080

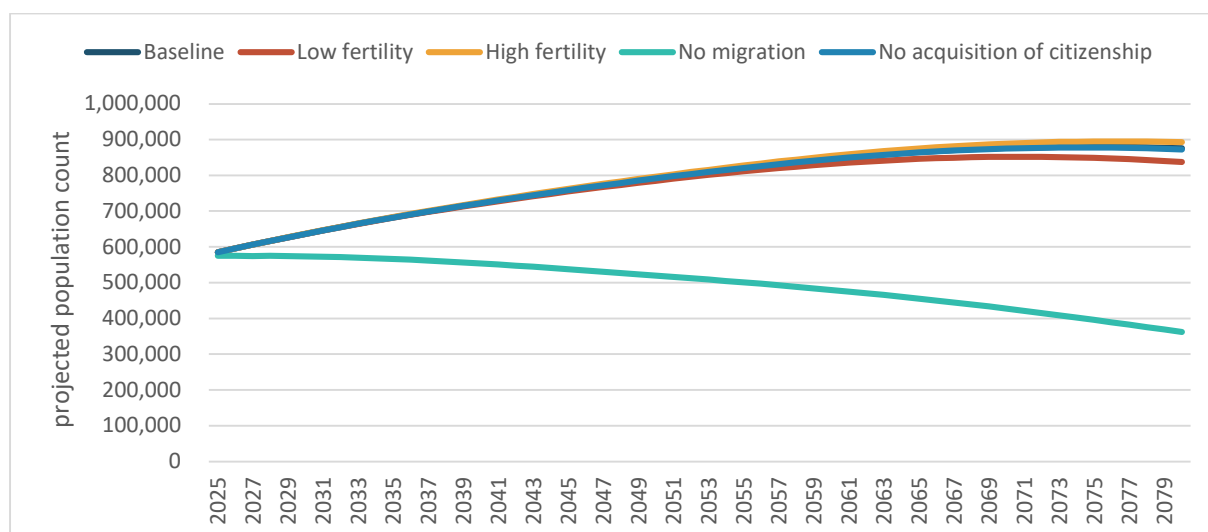


Chart 6 shows the projected population counts for the Maltese resident population under the alternative scenarios compared to the baseline. In the no migration scenario (alternative scenario 3), the Maltese resident population steadily declines throughout the projection horizon. This decline occurs because, as previously explained, the stability of the Maltese resident population in the baseline scenario is largely due to foreign residents acquiring citizenship. Without migration, the foreign resident population grows more slowly, resulting in fewer people eligible to acquire citizenship. When acquisition of citizenship is removed from the baseline scenario (alternative scenario 4), the Maltese resident population growth closely follows the no migration scenario. This indicates that the long-term stability of the Maltese population is dependent upon the presence of the foreign resident population, given the combination of low net migration and negative natural increase.

The two fertility scenarios have similar effects on the Maltese resident population as on the total resident population. The low fertility scenario (alternative scenario 1) results in a smaller population in 2080, with 388,966 people—18,292 fewer than the baseline. The high fertility scenario (alternative scenario 2) produces a slight population increase by 2080, reaching 416,973 people—9,715 more than the baseline.

Chart 6: Maltese resident population count from the baseline scenario and alternative scenarios: 2025-2080

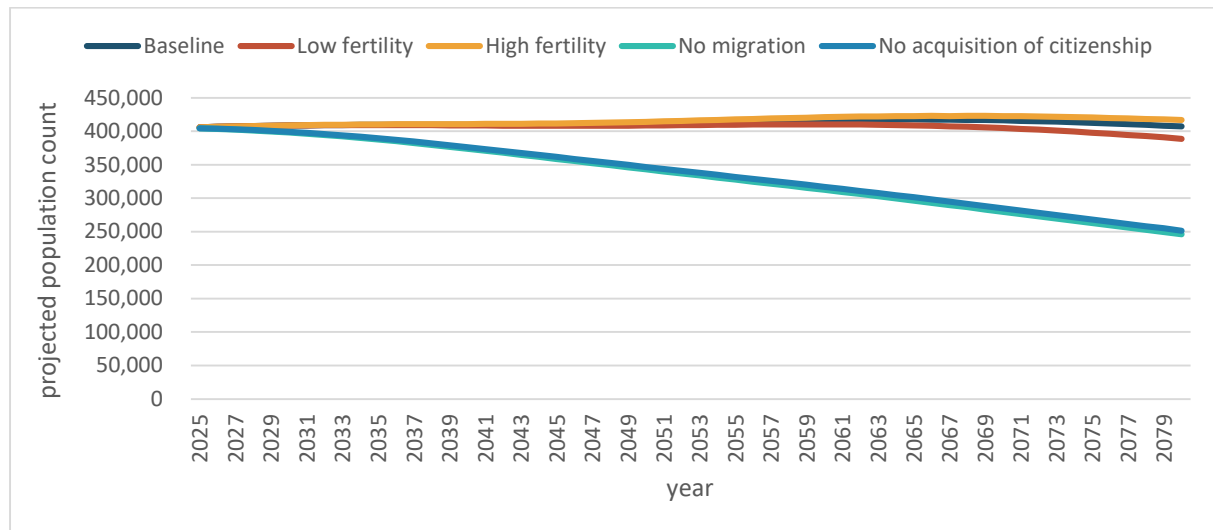
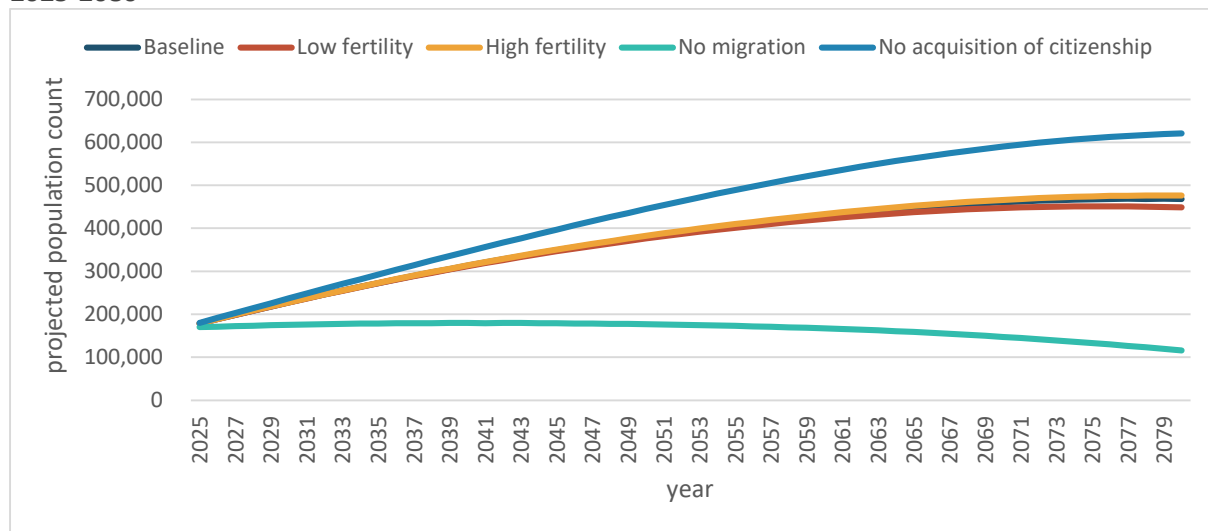


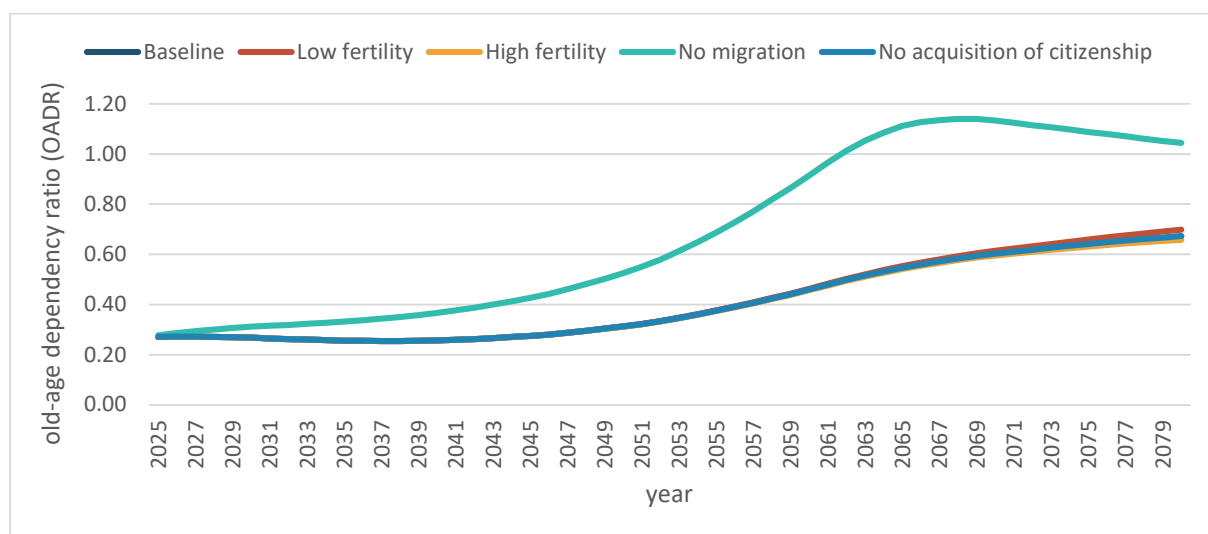
Chart 7 shows the projected population counts for the foreign resident population under the alternative scenarios compared to the baseline. For the foreign resident population, the no migration (alternative scenario 3) and no acquisition of citizenship scenarios (alternative scenario 4) exhibit opposing patterns of growth. In a no migration scenario the foreign resident population would only grow through natural increase. This would lead to minimal annual growth up to 2041, followed by population shrinkage from 2042. In a scenario with no acquisition of citizenship, migration would continue as assumed in the baseline scenario however no foreigners would acquire citizenship along the duration of the projection horizon meaning the stock of foreigners would grow to 620,709 by 2080 – 152,438 more than the baseline scenario. As expected, a low fertility scenario (alternative scenario 1) leads to a smaller foreign resident population by 2080, 448,253 – 20,018 less than the baseline. While a higher fertility scenario (alternative scenario 2) leads to a marginally higher foreign resident population by 2080, 476,237 – 7,966 more than the baseline.

Chart 7: Foreign resident population count from the baseline scenario and alternative scenarios: 2025-2080



In terms of the age structure of the total resident population, again the no migration scenario has the most significant impact on population structure. If no migration occurs along the projection horizon (alternative scenario 3), the OADR is expected to peak at 1.14 by 2068. Although it would begin to decline thereafter, it is expected to remain above 1 until the end of the horizon. On the other hand, both the low and high fertility scenarios (alternative scenarios 1 and 2) will lead to only small changes to the OADR when compared to the baseline. While the OADR for the baseline scenario is projected to be 0.67 by 2080, for the high fertility variant this will be slightly lower at 0.66, while for the low fertility variant this will be slightly higher at 0.70. In a scenario where there is no acquisition of citizenship (alternative scenario 4), the OADRs would mirror that of the baseline scenario since the components affecting age structure would be unchanged (Chart 8).

Chart 8: Old-age dependency ratios (OADRs) for the total resident population from the baseline scenario and alternative scenarios: 2025-2080



Methodological notes

A population projection is an estimate of what the future size and structure of a population might look like based on knowledge of past trends and assumptions about future changes in key demographic factors.

This projection presents the baseline scenario and three alternative scenarios resulting from sensitivity analysis. The baseline scenario is considered the most likely scenario for the future given current trends in the input demographic components. Conservative assumptions have been set based on expected future development of the input components when considering current trends and demographic principles of population dynamics.

Population projections provide hypothetical scenarios and are to be considered a "what-if" exercise showing potential future population changes by age and sex. They are not precise predictions, but rather conditional forecasts based on assumptions that may or may not hold true over time. When using these projections, one must remember there is always an inherent level of uncertainty when setting assumptions into the future. Uncertainty is expected to increase as the projection moves farther away from the base population, meaning projections of the near future are expected to be more reliable than those extending into the long-term.

Concepts and definitions

- **Acquisition of citizenship:** A legal process where a non-citizen acquires citizenship through naturalisation or registration.
- **Age-Specific Fertility Rate (ASFR):** The number of resident live births occurring to resident females in a specific age group during a given year per 1,000 mid-year resident female population in that age group in the same year.
- **Age-specific mortality rate (ASMR):** Annual number of resident deaths occurring within specific age groups per 1,000 mid-year resident population.
- **AutoRegressive Integrated Moving Average (ARIMA) model:** The model incorporates three components – autoregressive component (p), integrated component, (d) and moving average component (q). Component p models the relationship between past values to predict current values. Component d refers to the differencing of the data to make the series stationary i.e. constant mean and variance over time. Component q uses past forecast errors (residuals) to correct and improve current predictions. Together, these components allow ARIMA models to capture patterns, trends, and noise in time series data to make forecasts about future values. The model can be tailored to fit specific data by choosing appropriate values for p , d , and q .
- **Chiang's formula:** A method in demography for estimating life expectancy and its variance using life table data. Chiang's formula is used to convert ASMRs into the probability of dying within an age interval by accounting for the rate of death and the average fraction of the age interval lived by those who die.
- **Closed population:** A population with no migratory flows either in or out, meaning changes in the population size occur only through births and deaths, that is, natural increase.

- **Cohort-component model:** A standard demographic method used to project a population's future size and structure. It works by dividing the population into age–sex cohorts and then projecting each cohort forward in time, while accounting for the fertility, mortality and migration processes.
- **Convergence point:** The year when the target value is set to be reached in the model. This may not necessarily be a year within the projection horizon but may go beyond the horizon.
- **Crude birth rate:** The number of resident live births per 1,000 mid-year resident population.
- **Crude death rate:** The number of resident deaths per 1,000 mid-year resident population.
- **Emigration:** Emigration is the action by which a natural person leaves his or her usual residence in a particular country with the intent to settle permanently in another country for an expected minimum duration of 12 months.
- **Exit rates:** The proportion or frequency of migrants leaving the country per year, relative to their year of entry into the country.
- **Exponential model:** A mathematical function used to describe situations where a quantity increases or decreases at a rate proportional to its current value. This means the rate of change depends on the size of the quantity itself, leading to rapid increases or decreases over time.
- **Immigration:** The action by which a natural person establishes his or her usual residence in another country or region to which they are not native in order to settle there for a period that is or is expected to last a minimum of 12 months.
- **Infant mortality:** The number of deaths of infants under 1 year of age in a given year per 1,000 resident live births in the same year.
- **Life expectancy (LE):** A population based statistical measure of the average number of years a person has before death. Life expectancies can be calculated for any age and denote the number of years a person can, on average, expect to live given the age they have attained during the reference year.
- **Life table:** A tabular, numerical representation of mortality and survivorship of a cohort of births at each age of life. It comprises an array of measures, including probabilities of death, probabilities of survival and life expectancies at various ages.
- **Logarithmic scale:** Method of measuring or displaying numerical data where the position of each value is determined by the logarithm of the value rather than the value itself. Unlike a linear scale where equal distances represent equal increments, on a logarithmic scale, equal distances represent equal ratios or multiplicative factors.
- **Moving-average method:** A technique used to analyse data points by creating a series of averages of different subsets of the full data set. It is commonly used to smooth out fluctuations in data.
- **Mid-year population:** Calculated by averaging start-of-the-year and end-year population estimates. The mid-year population is used in rate estimation because it provides an average population size over the entire year, which more accurately reflects the population at risk during the period.
- **Natural increase:** The difference between the number of resident live births and the number of resident deaths during a reference year.
- **Old-age dependency ratio (OADR):** The ratio of the number of elderly people aged 65 and over relative to the working-age population aged 16 to 64.

- **Projection horizon:** The length of time, into the future, over which predictions are made in a projection.
- **Push and pull factors:** Push factors are conditions in the country of origin that drive people to leave their current location (emigration), while pull factors are conditions in the country of arrival that attract people to the new location (immigration).
- **Quadratic spline function:** A type of piecewise polynomial function used in numerical analysis and approximation. A quadratic spline will fit a quadratic curve between each consecutive pair of points, with the condition that the function and its slope match at the boundaries between intervals.
- **Random walk with drift:** A time series model where the value at a given time equals the previous value plus a constant average change (drift term) and a random shock or error term.
- **Sensitivity analysis:** The process of assessing how changes in input variables or assumptions in a statistical model affect the outcome or results.
- **Total fertility rate (TFR):** The number of children that would be born to a female if she were to live to the end of her child-bearing years and bear children in accordance with current age-specific fertility rates.
- **Usual residence:** Refers to the place where a person normally spends the daily period of rest, regardless of temporary absences for purposes of recreation, holidays, visits to friends and relatives, business, medical treatment or religious pilgrimage.

Usual residents of a specific geographical area are:

- those who have lived in their place of usual residence for a continuous period of at least 12 months before the reference time; or
- those who arrived in their place of usual residence during the 12 months before the reference time with the intention of staying there for at least one year.

Data sources

Population projection estimation requires a base population and an input time series to estimate the future development of the main demographic components – fertility, mortality and migration. The base year for this projection is end of year 2024, with the first and final projected years being 2025 and 2080, respectively. The table below outlines the data sources for the inputs used in this projection:

Component	Description	Source
Base population	Usual resident population by single years of age, sex and broad citizenship category (Maltese/foreign) as at end 2024	Population and Migration Unit, National Statistics Office Malta.
Fertility	Age-specific fertility rates (single years of age) for Maltese and foreign resident mothers separately: 2012 – 2024. Rates are estimated using resident live birth data split by citizenship of mother and age at birth as numerator, and mid-year resident population data for females split by citizenship and age as denominator.	Population and Migration Unit, National Statistics Office Malta.
Mortality	Age-specific mortality rates (single years of age) for total resident males and females separately: 2012 – 2024 Rates are estimated using resident death data split by age at death and sex as numerator, and mid-year resident population data split by age and sex as denominator.	Population and Migration Unit, National Statistics Office Malta.
Migration	Immigration and emigration counts by single years of age, sex and broad citizenship category (Maltese/foreign): 2015 – 2024 Exit rates estimated using residence permit data for foreign migrants entering and exiting the population during the period 2013 – 2024. Acquisition of citizenship data by age and sex: 2012 – 2024	Population and Migration Unit, National Statistics Office Malta.

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