te kaunihera ā-rohe o matamata-piako district council

Kaunihera | Council

Ngā Tāpiritanga – Pūrongo | Attachments – Reports

ATTACHMENTS UNDER SEPARATE COVER

Notice is hereby given that an ordinary meeting of Matamata-Piako District Council will be held on:

Ko te rā | Date:	**Wednesday 25 March 2026**
Wā | Time:	**9:00**
Meeting Room:	**Council Chambers**
Wāhi | Venue:	**35 Kenrick Street TE AROHA**

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THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

2023-base Population, Family and Household, and Labour Force Projections for the Waikato Region, 2023-2073

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Commissioned Research Report (Final)

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**2023-base Population, Family and Household,
and Labour Force Projections
for the Waikato Region, 2023-2073**

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The views expressed in this report are those of the authors and do not reflect any official position on the part of the University of Waikato.

Disclaimer

The projections discussed in this report are based on historical data and assumptions made by the authors. While the authors believe that the projections can provide plausible and indicative inputs into planning and policy formulation, the reported numbers cannot be relied upon as providing precise forecasts of future population levels. The University of Waikato will not be held liable for any loss suffered through the use, directly or indirectly, of the information contained in this report.

Acknowledgements

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Executive Summary

This report outlines a set of 2023-base demographic projections of the Waikato Region, and all of the territorial authorities that are wholly or substantively contained within the region. The demographic projections include three variants (low; medium; and high) for each of population, family and household, and labour force, to a projection horizon of 2073.

The projections of total and age- and sex-specific populations were prepared using a multi-regional cohort component model that covers the whole of New Zealand (except the Chatham Islands Territory), and incorporates separate components of population change for internal migration flows (based on a spatial interaction model) and international migration flows (immigration and emigration). Family and household, and labour force, projections were then derived from the population projections, by applying assumptions about living arrangement type rates and labour force participation rates respectively.

The overall picture in the demographic projections is one of regional population growth throughout the projection period. However, that growth is projected to be much slower for most TAs than their recent experience, and not all TAs have the same trajectories of population change and the contributing factors, and five main types are noticeable. First, Thames-Coromandel District, with its much older population age structure is projected to experience initial population growth which peaks and then declines in the medium-variant projection. Second, Hauraki, Matamata-Piako, Waipā, and Taupō Districts have similar components of population change to Thames-Coromandel District but experience population growth in the medium-variant projection. Third, Waikato District and Hamilton City are projected to experience substantial overall population growth in the medium-variant projection. Fourth, Ōtorohanga District and South Waikato District are projected to experience overall population growth in the medium-variant projection, but to a lesser extent than Waikato District or Hamilton City. Finally, Waitomo Districts is projected to experience population decline in the medium-variation projection.

In comparison with the SNZ 2023-base projections, these projections are higher for Thames-Coromandel, Hauraki, and Waikato Districts, but lower for Matamata-Piako, Ōtorohanga, Waitomo and Taupō Districts and Hamilton City, while the projections for Waipā and South Waikato Districts are similar. The key differences arise from SNZ's higher projections for fertility and net international migration.

Overall, the number of households is projected to closely follow the trajectory of the population for each territorial authority, but made up of fewer couples with children and two-parent families, and more one-parent families and one-person households. The labour force projections also closely follow the trajectory of the population for each TA.

Finally, this report offers some suggestions for future improvements to the model, assumptions, and associated projections.

1. Introduction

On behalf of the FutureProof partners,[1] the Waikato Regional Council (WRC) approached the University of Waikato in 2022 with a request to produce new Territorial Authority (TA) level population, family and household, and labour force projections for the Waikato Region, subsequent to the release of data from the 2023 Census. These projections use a multi-regional cohort component model that covers the whole of New Zealand (except the Chatham Islands Territory). The model incorporates separate components of population change for internal migration flows (based on a newly-developed spatial interaction model) and international migration flows (immigration and emigration). This represents continuing improvement on previous models, including the Whole-of-Waikato (WOW) population model (Cameron 2020a; 2020b; 2020c; Cameron and Cochrane, 2014a; 2015; 2016; Cameron *et al*., 2007; 2008; Jackson et al., 2014b), and the model used in the 2018-base projections (Cameron and Cochrane, 2021). The population outputs of this model are also a component of the Waikato Integrated Scenario Explorer (WISE) model (Rutledge *et al*., 2008; 2010), a systems-based integrated model that incorporates economic, demographic, and environmental components across the entire Waikato Region.

This report briefly summarises the Waikato 2023-base demographic projections for TAs in the Waikato Region. The methodology underlying the new population model is described in detail, along with the assumptions that were applied for the 2023-base projections. This model represents an improvement on previous models (e.g. Cameron and Cochrane, 2014; 2015; 2016; 2021), as it uses a spatial interaction model to derive internal migration flows, rather than the gravity model that was used in the 2018-base projections (Cameron and Cochrane, 2021). The spatial interaction model improves on a standard gravity model because it allows the flows of internal migrants between two TAs to be affected by the whole system of migration flows, rather than only by the populations of the origin and destination TAs and the distance between them (Cameron and Poot, 2024). In addition, the new model separates Auckland into its 21 component local boards, allowing for more granular internal migration flows to be estimated and reducing any bias associated with having one large TA within the internal migration model. The family and household, and labour force, projections derived from the population

[1] Hamilton City Council, Matamata-Piako District Council, Waikato District Council, Waikato Regional Council, and Waipā District Council.

projections follow a similar methodology as that employed in previous projections (Cameron and Cochrane, 2016; 2021).

This project continues to build on the pioneering demographic projections work by the University of Waikato (Cameron *et al*., 2007; 2008). The model has developed over time, and the methodology and assumptions that are now employed are substantially different from those adopted for official Statistics New Zealand (SNZ) projections. The population model generates projections for all of the territorial authorities and local boards (TALBs) in New Zealand (with the exception of Chatham Islands Territory). However, in this report we limit ourselves to reporting the results for TAs that are wholly or substantively contained within the Waikato Region.

Three projection variants were developed for the TA-level population, family and households, and labour force: (1) a low-variant; (2) a medium-variant; and (3) a high-variant. As discussed in Section 2.8 of the report, these three variants should be interpreted as individual scenarios from the many possible futures that could be realised for population, family and households, and the labour force. In sum, this project involved calculating population, family and household, and labour force projections for each TA in the Waikato Region, and for the region in total, for each of the three variants (low, medium, and high). These projections feed into a companion report on population, and family and household, projections at the more spatially-disaggregated SA2 level (Cameron, 2025).

The projections were delayed due to later-than-expected release of necessary data from the 2023 Census of Population and Dwellings. In particular, the 2023-base Estimated Resident Population data for June 2023 was only updated and made available by SNZ in early 2025.[2] That delay meant that these population projections were released almost concurrently with the 2023-base subnational population projections developed by Statistics New Zealand.[3] Thus, this report compares both the University of Waikato projections and Statistics New Zealand projections, in relation to total population.

The remainder of the report is structured as follows:

- Section 2 briefly summarises the data and methodology used in preparing the projections;

[2] See https://www.stats.govt.nz/information-releases/subnational-population-estimates-at-30-june-2024-2018-base/.
[3] See https://www.stats.govt.nz/information-releases/subnational-population-projections-2023base-2053/.

- Section 3 presents and briefly discusses the national-level population projections, obtained by summing the TA-level projections for the entire country;
- Section 4 presents and briefly discusses the TA level demographic (population, family and household, and labour force) projections, for all (low-variant, medium-variant, and high-variant) scenarios; and
- Section 5 concludes.

2. Data and Methods

2.1 Data

The data used in the construction of these projections were sourced from Statistics New Zealand (SNZ). This includes national and subnational data from the five-yearly Census of Population and Dwellings (2013, 2018, and 2023), SNZ national and subnational population estimates, national and subnational period life tables, national and subnational vital statistics data, the SNZ subnational demographic projections series, and the reported assumptions underlying those projections. The TA-level boundaries for the projections are consistent with boundaries at the time of the 2023 Census of Population and Dwellings.

In each case, the TA-level projections presented in this report are for the whole territorial authority. In the case of the Waikato Region projections (see Section 4.11), the projections are for the whole Waikato Region. The regional projections require some post-hoc calculations because of the inconsistency in boundaries between TAs and the region. Specifically, in the Waikato region projections we assume that the proportion of the TA-level population (and families and households, and labour force) that lives outside of the region (for Waitomo and Taupō Districts), and the proportion of the TA-level population (and families and households, and labour force) that lives inside the region (for Rotorua District), remains constant over time.

2.2 The Cohort Component Model

The most common methodology used to generate population projections relies on the cohort component model, which dates back at least to Whelpton (1928). This is the methodology used by SNZ, the major supplier of data on current and projected population size, growth and structure for New Zealand regions and TALBs. In recent years, new methodologies have been developed for population projections, such as stochastic and microsimulation approaches (see e.g. Dharmalingam and Pool, 2006). This report substantively applies the same methodology for the cohort component model used in the 2018-base projections (Cameron and Cochrane, 2021), which was an improvement on the methodology originally developed by Cameron et al. (2007; 2008) and used in subsequent projections (Cameron 2020a; 2020b; 2020c; Cameron and Cochrane, 2014a; 2015; 2016; Jackson et al., 2014b).

The general approach that was used in developing the population projections is as follows. The current population (base population) is first defined, and then assumptions are made about demographic changes to this population, which are then applied using the cohort component model. The cohort component model is a stock-flow model based on the following fundamental 'accounting identity' of population growth:

usually resident population in area *i* at the end of year *t*

= usually resident population in area *i* at the beginning of year *t*

+ births to mothers residing in area *i* during year *t*

– deaths of residents of area *i* during year *t*

+ inward migration from other regions into region *i* during year *t*

– outward migration of residents from area *i* to other regions during year *t*

+ inward migration from overseas into region *i* during year *t*

– outward migration of residents from area *i* to overseas during year *t*

Starting with a given base year usually resident population at 30 June (see Section 2.3), the usually resident population one year later is calculated using the equation above. This end-year usually resident population becomes the start-year usually resident population at 30 June for the next iteration of the model. This procedure is repeated for each year through to the end of the projection period (the projection horizon), and separately for each sex. Separate assumptions are used for each of the demographic 'drivers'. Births are derived by multiplying age-specific fertility rates by the numbers of women of childbearing age (13-49) (see Section 2.4). Deaths are derived by multiplying age- and sex-specific mortality rates by the numbers of people of each age and sex (see Section 2.4). Age- and sex-specific internal migration flows are derived by applying an age-sex-specific migration profile to total internal migration flows between pairs of TAs derived from a spatial interaction model (Cameron and Poot, 2024). Age- and sex-specific international migration flows are derived by applying an age-sex-specific migration profile to total international migration flows (separately for immigration and emigration).

The procedure for deriving estimates of migration flows is a key departure from the method employed by SNZ, and is also the main improvement on the methods previously employed in projections by the University of Waikato (e.g. Cameron and Cochrane, 2016). The latest iteration of this model moves from using a gravity model of internal migration flows (Poot et al., 2016) to a spatial interaction model (Cameron and Poot, 2024) (see Section 2.5). Another key departure from the modelling approach used by SNZ is that our model is bottom-up, rather than top-down (Willekens, 1983). A top-down approach projects the population at the national level first, using a national-level model, then projects each sub-national area either separately or as part of a multi-regional model. The sub-national projections in a top-down approach are constrained to sum to the previously determined national projection. A bottom-up approach instead projects each subnational area separately first, and derives a national projection as a sum of the subnational projections. The bottom-up approach has the advantage of more accurately reflecting differences in sub-national drivers of population change; however, the lack of an 'adding-up' constraint could lead to unrealistic national-level projections (which can be addressed through appropriate calibration of the model, as described in Section 2.8). For more on the advantages and disadvantages of top-down versus bottom-up approaches to population projections, see Cameron et al. (2021).

The remainder of this section describes the methods used for deriving each of the components used in the cohort component model, as well as the methods used to validate and calibrate the model. Finally, the methods employed in the family and household projections and labour force projections are described.

2.3 Base Populations

The base populations used for the projections were the Estimated Resident Populations (ERP) at 30 June 2023, revised by SNZ in early 2025. As this ERP is only reported by SNZ in 5-year age groups, the single-year age groups necessary for the population projection model were derived by interpolating the ERP for each territorial authority using the TA-level Census

Usually Resident Population (CURP) counts by single-year-of-age from the 2023 Census of Population and Dwellings. Separate interpolations were undertaken for each sex.

2.4 Fertility and Mortality Assumptions

The fertility and mortality assumptions used in the projections were initially based on the subnational 'medium' fertility and mortality assumptions used by SNZ in their 2018-base subnational population projections. More recent SNZ assumptions (i.e. those used in their 2023-base subnational population projections) were not available at the time that these projections were developed. Moreover, having considered alternative time series for fertility and mortality, in the past the assumptions used by SNZ with respect to fertility and mortality in their subnational population projections have proven to be adequate for our purposes (see for example Cameron *et al*., 2007; 2008), and they remain relevant and generally unbiased even five years later. As SNZ use past fertility and mortality (survivorship) rates based on the official deaths and births statistics to develop their projections, the SNZ assumptions therefore represent an appropriate starting point.

Age-specific fertility rates by single-year-of-age (of the mother) were derived by first interpolating the five-year subnational age-specific fertility rate using the national-level age-specific fertility rate profile by single-year-of-age. The resulting profiles were then scaled to match the projected total fertility rate (from SNZ) for each territorial authority. The total fertility rate for each territorial authority was assumed to follow the SNZ projections to 2048 then remain invariant after 2048. Sex at birth was assumed to follow a constant pattern similar to past trends, with 105.5 males for every 100 females at birth.

However, as we have found during past projections (see Cameron and Cochrane, 2021), SNZ fertility assumptions generate too many births at both the national and subnational levels, and therefore result in a projected national population that was implausibly high. Following Cameron and Cochrane (2021), we scaled the SNZ fertility assumptions for each TA down so that they replicated the 2023-2025 total number of reported births, then applied the TA-level scaling factors to all of the future projected age-specific fertility rates. Ultimately though, a better approach for future projections may be to generate our own age-specific fertility rate projections that adequately capture current fertility trends. We leave this as an exercise for future improvements in the projections model.

In terms of mortality, age-specific survivorship rates by single-year-of-age and sex were derived by first interpolating the survivorship rates from the subnational abridged life tables for each territorial authority using the national life tables by single-year-of-age. The resulting profiles were then scaled to match the projected life expectancy at birth for each territorial authority. Life expectancy at birth for each territorial authority was assumed to follow the SNZ projections to 2048, then continue to improve in a linear fashion through until 2073. This follows the same process as applied in the most recent projections (Cameron and Cochrane, 2021).

2.5 Internal Migration Model

The 2018-base population projection model included a gravity model of migration for projecting internal migration flows. The gravity model of migration is an empirical regularity, and recognises that the migration flow between two places (the origin *i*, and the destination *j*) depends on the 'economic mass' of the origin and destination (proxied by the population size), and the distance between them (Poot et al., 2016). Specifically, migration flows (in both directions) between larger origins and destinations, and between places that are closer together, are substantially larger (holding other factors constant) than migration flows between smaller origins and destinations, and between places that are further apart.

In these projections, we further developed this approach by adopting a spatial interaction model (the 'Alonso model'), which is a more generalised approach to modelling directional migration flows (Alonso, 1978; Cameron and Poot, 2024), and which we expected would require less calibration than the gravity model (see Cameron and Cochrane, 2021). Similar to the gravity model used in the 2018-base projections, the Alonso model relates internal migration flows positively to population in the origin and destination TALBs, and negatively to the distance between them. The key difference with the gravity model is that the Alonso model includes two additional terms. The first is an index capturing the 'draw' of other TALBs when modelling out-migration from a given origin (how attractive the alternatives are). The second is an index of the 'competitiveness' of each TALB as a destination, relative to all other TALBs, when modelling in-migration. In a standard gravity model these competition and crowding-out effects are implicitly set to zero, whereas in the Alonso model they are explicitly modelled (Cameron and Poot, 2024). As a result, all migration flows are interdependent and respond to population changes anywhere in the system, particularly in large TALBs such as those in

Auckland. To avoid bias from having a single very large TA, we therefore split Auckland into its 21 constituent local boards.

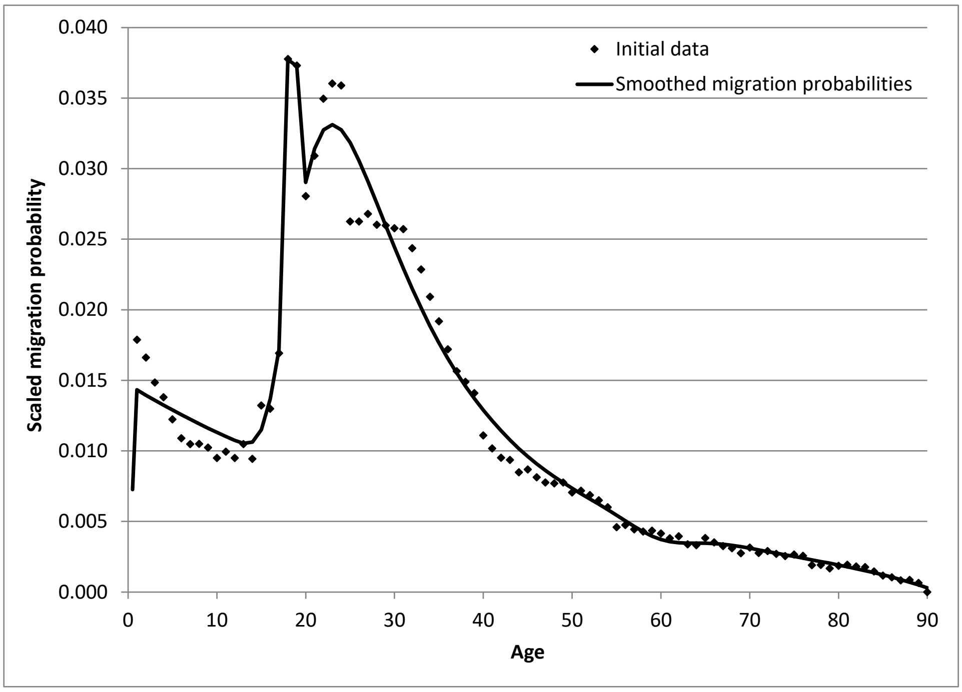
The spatial interaction model (Alonso model) was estimated using 2023 Census data on internal migration flows, population estimates, and inter-TA distances. Internal migration flows data were derived from the Census question on address one year ago, combined with current address. We used those data to construct an origin-destination matrix for all people who answered the address-one-year-ago question in the 2023 Census. We prefer the address-one-year-ago data over address-five-years-ago data that was used in the 2018-base population projections, because it matches the annual steps within the population projections model. Population data were the estimated usually resident population by TA at 30 June of 2022 (the population at the start of the one-year period). Distance was the straight-line distance between the geographic centroid of each TA. Poot et al. (2016) showed that gravity models are robust to the choice of alternative distance measures, and we expect that this also holds for more general spatial interaction models. In addition, we included dummy variables for internal migration flows between geographically contiguous (i.e. neighbouring) TAs, and between the North and South Islands. Past research has shown that internal migration flows between the islands are much lower than can be explained purely by distance (Poot, 1986).

The spatial interaction model was embedded within the population model. The projected internal migration flows depend on the populations of origin and destination at a given point in time, as well as the time-invariant distance, contiguity, and Cook Strait variables. The embedding of the spatial interaction model within the population model represents one of the key innovations in this latest population model (Cameron and Poot, 2024), building on past innovations in including gravity models within population projections, that we have developed over a number of years (Cameron and Poot, 2013; 2014a; 2014b; 2016).

The spatial interaction model provides a projection of the *total* annual internal migration flow between each pair of origin and destination TAs in each year. To convert this total into *age-sex-specific* migration flows, we first estimated a profile of the age-specific in-migration rates based on address-five-years-ago data for each TA from the 2023 Census. The age-specific migration profile for each TA was based on data for that TA as a destination, as this was expected to more accurately reflect age-specific origin-destination internal migration flows. These data were first smoothed using the model migration schedule method described by Rogers et al. (1978) and the Microsoft Excel algorithm developed by Wilson (2010). Then, a second round of smoothing was used to reduce high migration rates at older ages for some TALBs. Finally, each migration profile was standardised to sum to one. Separate migration profiles were not developed by sex, due to the sparse nature of the data for many TALBs. Instead, internal migration flows were assumed to be equally prevalent for each sex (in effect, each migration profile was converted to a sex-specific migration profile that was standardised to sum to 0.5). For some TALBs, the migration profile algorithm could not converge to a plausible profile. In those cases, mostly occurring for TALBs with small populations (and hence a small number of internal migrants), the profile for a neighbouring TALB was substituted. This process was not necessary for any TAs in the Waikato region.

An example of a resulting migration profile is shown in Figure 1, for Hamilton City. Note that there is a significant peak in migration flows to Hamilton City at young ages, followed by a tapering off at older ages. In contrast, other TALBs often have a peak of in-migration at older ages, representing retirement migration flows.

Figure 1: Age-specific in-migration profile for Hamilton City



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2.6 International Migration Assumptions

International migration flows represent the most challenging component of population change to project, due to the extensive uncertainty over their future trajectory. Following Cameron and Cochrane (2021), we adopted a fairly simple ARIMA(0,1,1) model (simple exponential smoothing), which appears to be the best model, in terms of both in-sample and out-of-sample performance. This model takes a long-run average level of immigration and emigration, and 'decays' deviations from that long-run average over time, until the flows reach the average.[4] The long-run average for both immigration and emigration was taken as the average annual level over the period from 1995-2025. The 2018-base projections used a constant long-run average, but in these projections we replaced that with a time trend that used the long-run average for 2026, then increased the long-run average gross immigration and emigration flows by 1.2 percent per year from 2027 onwards. This increase was based on long-run trends in the growth of immigration and emigration flows, as well as national population growth. The optimal 'decay rate' in the error correction model for immigration was 84 percent (meaning that the difference between the projected annual immigration flow and the long-run trend reduced by 84 percent each year), while the optimal 'decay rate' in the error correction model for emigration was 32 percent.

Figure 2 illustrates the actual and projected national-level immigration flows. All scenarios are presented (see Section 2.8 for further details on the different variant scenarios). This figure clearly shows the historically high immigration flows that New Zealand has experienced in recent years before and after the obvious decline in immigration flows due to the COVID-19 pandemic, as well as the variability in immigration flows. The long-term trend level of immigration, which is 116,074 per year in 2026, and trends upwards by 1.2 percent per year afterwards.[5] Figure 3 shows the corresponding data for emigration, with similar features, and

[4] Specifically, the econometric model is estimated in error correction format:

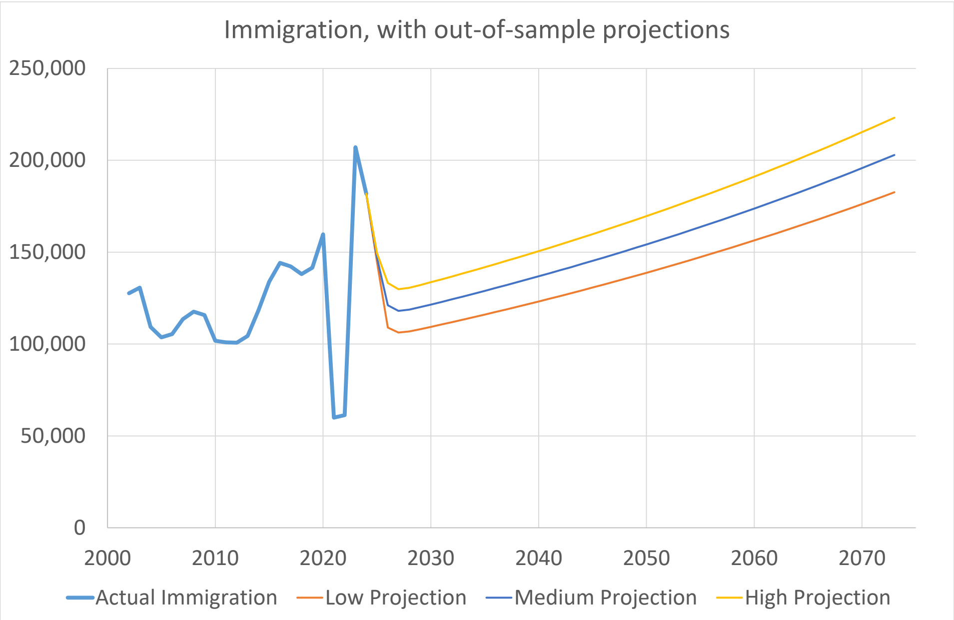
$$(Y_t - \hat{Y}_t) = \beta_0 + \beta_1(Y_{t-1} - \hat{Y}_{t-1}) + \varepsilon_t$$

Where Y_t and Y_{t-1} are the outcome variable (emigration or immigration) at times t and t-1 respectively, and $\hat{Y}_t$ and $\hat{Y}_{t-1}$ are fitted values at times t and t-1 respectively, estimated from a linear regression of the outcome variable on year. The coefficient β_0 is the average annual change in Y, i.e. $\overline{(Y_t - Y_{t-1})}$. The complement of coefficient β_1 (i.e. $(1 - \beta_1)$) is the decay rate, i.e. the rate at which deviations from long term trend reduce each year.

[5] The long-term trend level of immigration is constructed from Statistics New Zealand long-term data series (LTDS) values for 1995 to 2001 and annual arrivals data using the '12/16 rule' for 2002 to 2025. The data from the LTDS is scaled to be comparable to the more recent data, based on the ratio of LTDS to '12/16 rule' data for 2002 to 2004 (which are the only data that are comparable across the two data series).

a gradual error correction back to the long-term trend level of emigration, which is 88,821 per year in 2026, and trends upwards by 1.2 percent per year afterwards.[6] Figure 4 shows the data for net international migration (immigration minus emigration), where the high degree of uncertainty is clearly on display. It is also clear that in the first two years of the projection, net international migration is positive, but then drops significantly and then trends upwards thereafter. Figure 4 also shows the SNZ median stochastic projection for net international migration. The SNZ projection tracks higher than the medium projection over most of the projection period, but especially early on. For example, the SNZ projection of net international migration for 2028 is 34,500, compared with 18,170 for the medium projection. We observe, though, that net international migration for 2025 has tracked much lower than the SNZ projection of 25,000, being 13,700 for the June 2025 year.[7]

Figure 2: Actual and projection national-level immigration flows, 2002-2073



[6] The long-term trend level of emigration is constructed in the same way as for the long-term trend level of immigration.
[7] See: https://www.stats.govt.nz/information-releases/international-migration-june-2025/.

Figure 3: Actual and projection national-level emigration flows, 2002-2073

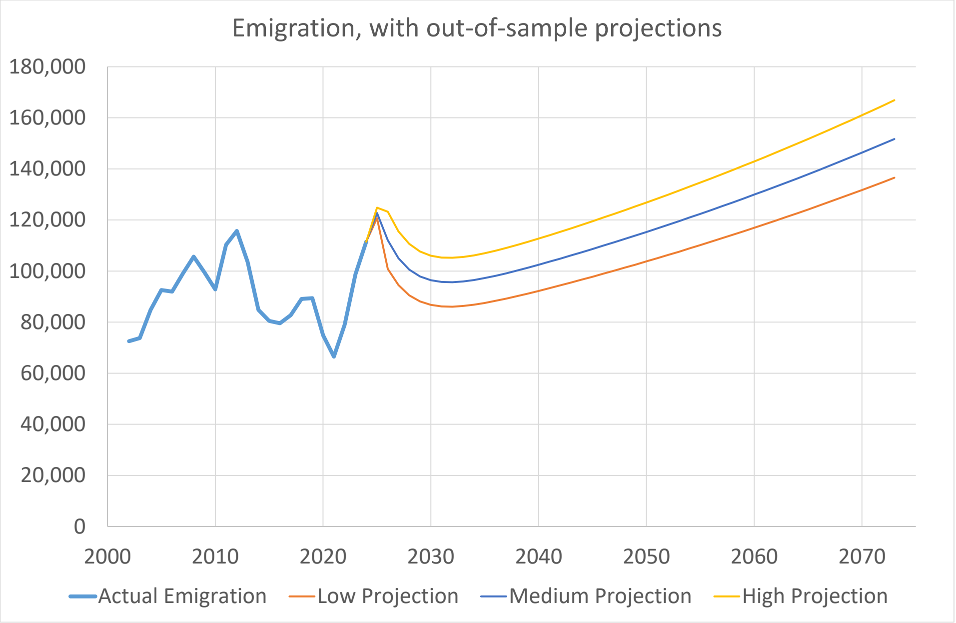
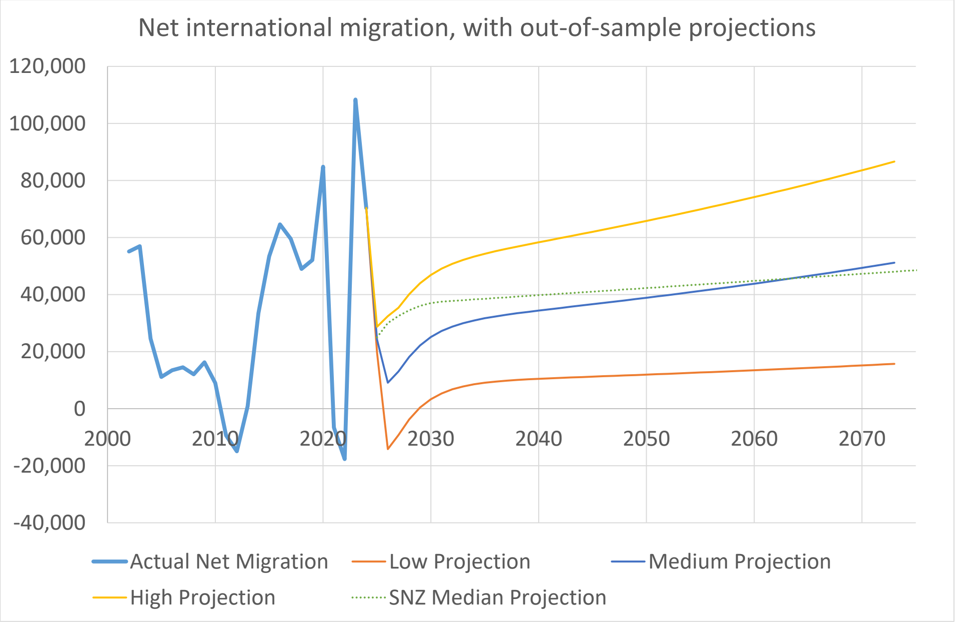


Figure 4: Actual and projection national-level net international migration flows, 2002-2073



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Similar to the gravity model of internal migration, the error correction models provide projections of annual *total* international migration flows in each direction (emigration and immigration), but at the national level. To apportion immigration and emigration flows by TALB, we first attempted structural modelling (as noted above). We then compared the TALB shares of immigration and emigration flows with TA shares of population in 2023 (using the subnational population estimates). Following Cameron and Cochrane (2021), this apportionment was based on a modified share of population. For the Waikato Region, the modified share of immigration for each TA was the share of population for TA, with the exception of Hamilton City, where the share was increased by 0.81 percentage points (being the average difference between Hamilton's population share and its share of past immigration).[8] Similarly, the modified share of emigration for each TA in the Waikato Region was the share of population for each TA, with the exception of Hamilton City, where the share was decreased by 2.29 percentage points (being the average difference between Hamilton's population share and its share of past emigration).[9]

That process provides TALB-specific *total* emigration and immigration flows. To convert these totals into age-sex-specific international migration flows for each TALB, we estimated separate of the age-specific immigration and emigration profiles based on address-one-year-ago data for each TA from the 2023 Census. The age-specific immigration profile for each TALB was based on data for that TALB as a destination, as this was expected to more accurately reflect age-specific international migration flows. The age-specific emigration profile for each TALB was based on data for that TALB as an origin for *internal* migration flows, because data on emigration flows are not available.[10] The process of developing the profiles was identical to that used for internal migration profiles, with each migration profile standardised to sum to one. Separate migration profiles were not developed by sex, again due to the sparse nature of the data for many TALBs. Similar to the case for internal migration profiles, for some TALBs, the migration profile algorithm could not converge to a plausible profile. In those cases, mostly occurring for TALBs with small populations (and hence a small number of internal migrants), the profile for a neighbouring TALB was substituted. This process was not necessary for any TAs in the Waikato region.

[8] Hamilton City is a significantly larger recipient of immigration flows than would be implied by its share of national population.
[9] Hamilton City is a significantly smaller contributor to emigration flows than would be implied by its share of national population.
[10] Emigrants are not observed in the Census because they have moved overseas.

2.7 Validation and Calibration of the Population Model

Once the population model was parameterised, it was validated to ensure fidelity of the model, i.e. that all components (fertility and births; mortality and survivorship; internal migration; and international migration) were working as intended. This process identified no issues with the structure or initial parameterisation of the model.

Calibration of the model involved several stages. First, the projected number of births, by TALB and in total for New Zealand as a whole, were compared with the actual number of births over the period from 2023 to 2025. As noted above, this resulted in a necessary downward adjustment to the projected total fertility rates for each TALB. Second, the total population of New Zealand was calibrated by comparing the growth rate with recent national population projections. This resulted in no adjustment to the model parameters, as it confirmed a plausible path for future national population (in total, and by age and gender) (see also Section 3). It also confirmed that using a trend for long-term change in net international migration was approach (see Section 2.6). Third, the total populations and growth rates for each TA were calibrated by adjusting the emigration shares, in order to more accurately reflect the relative growth rates from past subnational population projections. This approach to calibration differed from that used in the 2018-base projections, where fixed effects within the internal migration gravity model were adjusted as part of the calibration. Emigration shares is a more appropriate way to calibrate the model, as emigration is a calculated as a residual from the Census data, and is therefore subject to error. Following Cameron and Cochrane (2021), the medium-variant 2018-base SNZ projections were used as the baseline for these comparisons. Finally, the TALB-level age structures were calibrated through minor adjustments to the migration age profiles. This ensured that the model did not over- or under-project TALB-level migration flows into or out of certain age groups, unbalancing the resulting age distributions.

2.8 Low-variant and High-variant Population Projection Assumptions

Following calibration of the medium-variant population projection model (see Section 2.7), other projection scenarios were run. In addition to the baseline (medium-variant) projections outlined above, we present low-variant and high-variant population projections which are based on alternative sets of assumptions. These represent plausible alternative scenarios to the baseline (medium-variant) population projection scenario (see below on interpretation of the results).

For fertility and mortality, each age- and gender-specific rate (fertility, and mortality/survivorship) was multiplied by a shift factor, following Cameron and Poot (2010; 2011). The percentage change in each of the rates is given by k, whereby k is based on a distribution for fertility and mortality/survivorship. The entire deterministic path of fertility and mortality rates over the 2023-2073 projection period was shifted by the corresponding factors. In this way, setting all multipliers to zero would result in the baseline projection, and the multiplier was varied around zero to increase or decrease each rate.

Following Cameron and Poot (2010; 2011), distributional assumptions for each multiplier were based on observed data from 1950 to 2025. The fertility multiplier was assumed normally distributed with a mean zero and standard deviation of 1.25 (giving a range of about +/- 5% of the mean fertility rates). The survivorship multiplier was assumed normally distributed with mean zero and a standard deviation of 0.5 (i.e. giving a range of +/- 2% of the mean mortality rates).

For international migration (emigration and immigration), the high-variant projections assumed 10% lower emigration and 10% higher total immigration throughout the projection period, while the low-variant projections assumed 10% higher emigration and 10% lower total immigration throughout the projection period. These assumptions were based on observed variation in emigration and immigration over the period from 1985 to 2025, and approximately represent one standard deviation lower, and higher, net migration flows for the low-variant and high-variant projections respectively.

The internal migration model was not adjusted for the low-variant or high-variant projections from that used for the medium-variant projections. That is because internal migration is a means of distributing population within the country, so by definition has no role in creating higher or lower projected populations, when the population of the entire country is being projected. That is, if internal migration were increased for some TALBs, it must be reduced for other TALBs, because the overall sum of net internal migration must by definition be zero.

The interpretation of different projection scenarios is important. Specifically, the three variants (low, medium, and high) should be interpreted as individual scenarios from the many possible futures that could be realised for population, family and households, and the labour force. No scenario is any more likely than any other scenario of being the 'actual' path that future trends follow. However, the three variants (low, medium, and high) can be used to give a coarse representation of the uncertainty in the projections.

The medium-variant scenario represents approximately the centre of the distribution of all potential scenarios generated with this model and within the plausible distribution of assumptions. It is not exactly the middle of the distribution because the distribution of scenarios is likely to be asymmetric (for most TALBs, the distribution has more 'upside risk' than 'downside risk') – for a demonstration of this, see Jackson et al. (2014a; 2014b), which include both a medium scenario projection, and a median stochastic projection. The interval between the low-variant scenario and the high-variant scenario represents approximately a 67 percent projection interval of all potential scenarios generated with this model and within the plausible distribution of assumptions. This interpretation was demonstrated by Stoto (1983) and Alho et al. (2008), and has recently been employed by Cameron *et al*. (2021) in a book chapter on uncertainty in subnational population projections. Under this interpretation, the interval between the low-variant and high-variant projections should be expected to capture the actual future population approximately 67 percent of the time. Approximately 33 percent of the time, the actual future population can be expected to be either higher than the high-variant projection, or lower than the low-variant projection.

An alternative way of interpreting the three variants (low, medium, and high) is that the low-variant projection is broadly representative of the bottom one-third of all potential scenarios generated with this model and within the plausible distribution of assumptions. The medium-variant projection is broadly representative of the middle one-third of all potential scenarios generated with this model and within the plausible distribution of assumptions. The high-variant projection is broadly representative of the top one-third of all potential scenarios generated with this model and within the plausible distribution of assumptions.

Regardless of interpretation, it should be recognised that population projections are not a forecast of the future, unless they are considered alongside an appropriate measure of uncertainty. While the interval between the low-variant and high-variant projection adequately captures this uncertainty for the medium-variant projection, an even better method for representing uncertainty is to use stochastic population projections, where the uncertainty is directly modelled (e.g. see Cameron and Poot, 2010; 2011).

2.9 Family and Household Projection Methods and Assumptions

Projections of the future number of families and households were obtained by applying age- and gender-specific assumptions about future trends in living arrangement type rates (LATRs) and average household sizes to the projected population, as described in Cameron et al. (2007). The number of persons living in a particular living arrangement type is derived by multiplying the age- and gender-specific living arrangement type rate (LATR) by the number of persons at that age and gender and summating. LATRs can be thought of as the probability of an individual being in a particular living arrangement. Living arrangements include families (couples without children, couples with children, and one-parent families), other multi-person households (containing no families), single-person households, and people living in non-private dwellings (such as prisons, nursing homes, or student halls of residence). The number of households is made up of the number of family households (which is necessarily smaller than the number of families, because some households contain more than one family), other multi-person households, and single-person households.

We used LATRs and other assumptions (the average number of families per family household, and the average household size for other multi-person households) provided by SNZ, which were used in their 2018-base subnational family and household projections, as these were the best available data at the time of these projections. However, as noted in Cameron and Cochrane (2016) and Cameron and Cochrane (2021), applying the LATR assumptions of SNZ clearly leads to an over-projection of families and households, compared with Census data. In the current projections, we scaled the initial number of family households, other multi-person households, and single-person households to match the expected number in each TA. Those TA-specific scaling factors were then applied to the projected living arrangement type rates throughout the projection period, to ensure a consistent time series with the actual Census data on families and households in each TA.

Following Cameron and Cochrane (2021), LATRs were assumed to follow the SNZ projections to 2043, then continue to change in a linear fashion through until 2073. In contrast, the number of households per multi-family household and the number of persons per other multi-person household were assumed to follow the SNZ projections to 2043, then held constant from 2043 through until 2073.