Michael P. Cameron

The relative (un)certainty of subnational population decline

Introduction

"*Prediction is very difficult, especially about the future.*" This quote is attributed to Danish physicist and Nobel prize winner Niels Bohr, but the difficulty of making predictions does not stop us from making forecasts of economic, demographic, and other variables. Investors, businesses, policy makers and others use these forecasts to inform their decisions about investments and policy settings where understanding of the future trajectory and levels of costs and benefits are essential. One key example is forecasts of future population. The size and distribution (whether geographic, age, ethnic, or some other distribution) of the future population is a critical input into urban and other planning. Understanding the methods and limitations of forecasts is an important but often under-appreciated task for planners and policymakers.

Dr Michael Cameron is Associate Professor, Department of Economics, University of Waikato, and Research Associate, National Institute of Demographic and Economic Analysis (NIDEA), University of Waikato (mcam@waikato.ac.nz).

In this article, I draw on more than a decade of experience in developing population projections for local councils and others, as well as the latest in population projection methods, to provide an answer to the question: "Is population decline inevitable for New Zealand's rural and peripheral areas?" A recent term, coined by economist Shamubeel Eaqub (2014), 'zombie towns', refers to population centres facing irreversible population decline. However, such a categorical statement ('irreversible population decline'), does not reflect the uncertainty of population projections, or indeed the uncertainty of the future population distribution of New Zealand. Moreover, as I show in this article, it does not reflect the projected experience of the majority of territorial authorities (TAs) (or indeed, towns) in New Zealand, even many in rural or peripheral areas. While many areas are currently in decline, and these and others will decline in the future, such population decline is not certain except in a minority of cases that is large and growing.

In this article, I first outline some of the key points that decision-makers need to understand about population projections, focusing especially on the role and sources of uncertainty. I then briefly outline a recently developed state-of-the-art stochastic subnational population projection model (Cameron & Poot 2014a, 2016). Finally, I use the model to evaluate the probability of New Zealand's TAs experiencing population decline over the periods 2013–2023, 2033–2043 and 2053–2063. This exercise complements the analysis at the town level by Jackson and Brabyn (*infra*), and clearly charts the progression from subnational population growth to decline, particularly for rural and peripheral areas.

What everyone should know about population projections

The first thing that decision-makers should understand about population projections is the difference between a 'forecast' and a 'projection'. A population forecast is a 'best' estimate of the future population (and its distribution) at some future time. In contrast, a population projection is a measure of the future population that is based on a specific model with known and quantified assumptions that are incorporated into the model. A population projection is therefore not necessarily the same as a forecast, since alternative scenarios based on different sets of assumptions will naturally lead to different projections. A range of different sets of assumptions will lead to a range of different projections of the future population.

The second thing that decision-makers should understand is uncertainty. Population projections are uncertain. Uncertainty arises from several sources, including the correctness of the model (model uncertainty), the parameters or assumptions that drive the model (parameter uncertainty), and natural variation in the input variables for the model (parametric variability) (Kennedy & O'Hagan 2001).

Acknowledging that population projections are uncertain is challenging for decision-makers. It is attractive to believe, when looking at a single line on a graph tracking a given population projection or a single row of a table, that the numbers represent the 'one true future', because this makes decision-making much simpler. Several times I have encountered decision-makers who, despite understanding that projections are uncertain, are more than willing to ignore that uncertainty for the simplicity of a single 'magic number' population projection.

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The third thing that decision-makers should understand is that the degree of uncertainty in projections is not constant. It is greater the further into the future we project (for example, see Figure 1 below), as we can be more certain (or less uncertain) about the state of the world in the near future than we can about the far future. Uncertainty is also greater for smaller areas (for example, territorial authorities) than for larger areas (for example, regions) (Cameron & Poot 2011).

Fortunately, methods are available that explicitly quantify the degree of uncertainty in population projections. A relatively crude way of quantifying uncertainty is to create a small number of different population projection scenarios (for example, high, medium, and low scenarios). Until relatively recently, this was the approach adopted by Statistics New Zealand at both the national and subnational levels. Several problems arise with this approach, not least of which is that it makes little use of the known distribution of each parameter (fertility, mortality, and migration). To improve on this, over the last two decades or more demographers have increasingly begun to use stochastic (or probabilistic) population projection models (Tuljapurkar 1992; Bryant 2005; Bijak et al., 2015). These models draw repeatedly from the parameter distributions, creating hundreds or thousands of population projection scenarios. This allows a better understanding of the range of future population to be explicitly quantified. This approach was first piloted for New Zealand national projections by Wilson (2005) before being adopted by Statistics New Zealand (Dunstan 2011). At the subnational level, the method was first employed by Cameron & Poot (2010, 2011), and has since been applied several times (Cameron et al., 2014; Jackson et al., 2014).

A subnational stochastic population projection model

The workhorse of population projections methods is the cohort component model (CCM), which I employ at the TA-level (excluding the Chatham Islands). The CCM is simple, intuitive, and elegant. Population is assumed to change through only three components: (1) births; (2) deaths; and (3) migration. To project the population requires only projections of parameters for fertility (for example, age-specific fertility rates), mortality (for example, age-specific mortality or survivorship rates), and migration.

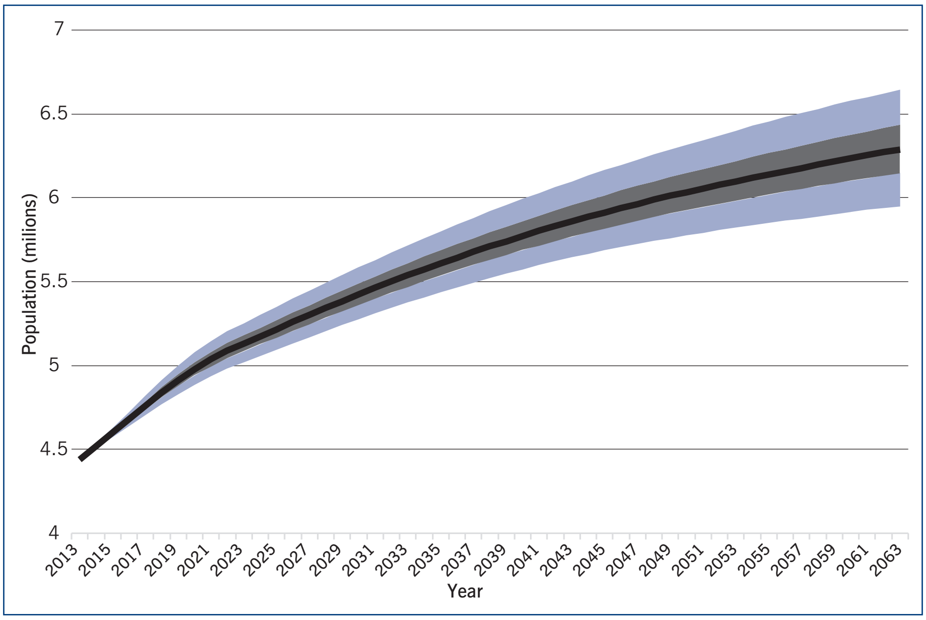
The model I employ is similar to that of Statistics New Zealand, but also different in significant and important ways (Cameron & Poot 2010, 2011, 2014a, 2016). The model uses the same subnational fertility and mortality assumptions as Statistics New Zealand, with a distribution around the median assumption based on past observations of fertility and mortality. The methods used to derive projections of fertility and mortality are fairly similar in most applications, and the degree of uncertainty is relatively low, so there is little added value in using our own projections.

In contrast, the projection of parameters that capture migration is not only the least certain, but also involves the greatest variation in methods. Statistics New Zealand's subnational population projections incorporate a projection of net migration as a single absolute number for each TA (which sum to net migration for New Zealand as a whole), which is then disaggregated by age and sex. In contrast, the model employed in this article improves on that method in two ways (the methods will be explained in greater detail in a forthcoming working paper). First, migration is disaggregated into international migration (emigration and immigration) and internal migration, which are each modelled separately. Emigration and immigration are each modelled as a single absolute number, similar to Statistics New Zealand (but for international migration in each direction separately, rather than net migration), and then allocated to TAs using a simple model based on population shares, which are then disaggregated by age-sex-specific migration profiles.

Second, internal migration is modelled using a gravity model. Gravity models are excellent tools for modelling directional migration flows and are widely used in trade as well as migration (Poot et al., 2016). The model explicitly recognises that the migration flow between two areas will depend on the population size of the two areas (larger populations in the origin or destination will lead to larger migration flows) and the distance between them (greater distances will lead to smaller migration flows). Gravity models of internal migration flows in New Zealand have recently been developed (Cameron & Poot 2014b; Poot et al., 2016).

The advantages of the model used here is that it allows us to derive population projections based on a full range of directional migration flows (to and from a given area, both internationally and internally within New Zealand). While this makes the model more complex, it also makes the model more believable for end-users since questions of where migrants are coming from (or going to) can be readily answered (Poot et al., 2016).

Figure 1: The relative (un)certainty of subnational population decline



Source: Author's projections

The subnational stochastic population projections model was run 1000 times, each time drawing new fertility, mortality, and migration parameters from their distributions. This number of projection runs is sufficient to establish the distribution of projected populations. The results presented below are based on these model runs, and are expressed probabilistically (i.e. as a probability that a given area will experience population decline over a given decade). These results can be evaluated in a vast number of ways. For simplicity, I look only at two 10-year periods: (1) 2023-2033; and (2) 2043-2053. I ignore the first decade of projections for two reasons. First, the degree of uncertainty is fairly low in the initial period, relative to later periods. Second, the initial period includes the current and historically high net migration that New Zealand is experiencing (and which has been included in the modelling assumptions), meaning that few areas are projected to experience population decline in the 2013–2023 decade. However, the current high net international migration is unlikely to continue indefinitely, so after 2023 the projected net international migration is assumed to fall back to levels seen historically. For each of the two decades, I compute the proportion of scenarios for each TA where population declines over the ten-year period.

Results

Figure 1 provides an illustration of a stochastic (probabilistic) population projection, for New Zealand as a whole. This projection was constructed bottom-up by summing the individual TA-level projections. The solid black line at the centre represents the median projection – this is the point where fifty percent of observed projections are above, and fifty percent of observed projection are below, for each point in time. It is important to note that the median projection does not represent a single projection scenario – it is constructed from all 1000 scenarios. The narrow dark grey band around the median projection is the 50 percent projection interval – 50 percent of the observations in each period fall within this band (and 50 percent outside of that band). The wider (and lighter-coloured) band around the 50 percent projection interval is the 90 percent projection interval – 90 percent of the observations in each period fall within this band, with 5 percent of observations above the top of this band, and 5 percent of observations below the bottom of this band.

Several points should be noted about the national projection in Figure 1. First, the historic period of high international immigration that New Zealand is experiencing is reflected in the high initial

Table 1: TAs facing probable population decline, 2023-2033 and 2043-2053

Probability of population decline	Year 2023–2033	Year 2043–2053
5-50%	Central Otago Mackenzie South Wairarapa Southland Thames-Coromandel	Hastings (+) Marlborough (+) Opotiki (-) Rotorua (--) Waimate (+) Waitaki (+)
50-90%	Clutha Gisborne Masterton Opotiki South Taranaki Stratford	Central Otago (+) Hurunui (++) Mackenzie (+) South Waikato (-) South Wairarapa (+) Tasman (++) Wellington (++)
90+%	Central Hawke's Bay Gore Grey Horowhenua Invercargill Kaikoura Kawerau Lower Hutt Otorohanga Porirua Rangitikei Rotorua Ruapehu South Waikato Tararua Wairoa Waitomo Wanganui Westland Whakatane	Buller (+++) Central Hawke's Bay Clutha (+) Gisborne (+) Gore Grey Horowhenua Invercargill Kaikoura Kawerau Lower Hutt Masterton (+) Otorohanga Porirua Rangitikei Ruapehu South Taranaki (+) Southland (++) Stratford (+) Tararua Upper Hutt (+++) Wairoa Waitomo Wanganui Westland Whakatane

N.B. (+) indicates a one-category increase in the probability of population decline; (++) indicates a two-category increase; (+++) indicates a three-category increase; (-) indicates a one-category decrease; and (--) indicates a two-category decrease.
Source: Author's projections

increase in population before flattening out. This is based on the international migration assumptions within the model, which are similar to those of Statistics New Zealand in terms of net international migration – approximately 50,000 per year for the first five years, decreasing to about 15,000 per year from 2023 onwards. Second, the degree of uncertainty in the projections increases over time, as represented by the widening of the 50-percent and 90-percent projection intervals. Third, as a whole, New Zealand is not projected to experience population decline before 2063 under the assumptions in this model. However, a focus on the projected population for New Zealand as a whole would mask substantial differences in the projected populations of different subnational areas, to which I now turn.

Table 1 lists the TAs that are projected to experience population decline in at least five percent of scenarios for each period (2023–2033; and 2043–2053). The TAs are categorised by the relative certainty/uncertainty of population decline into three categories: (1) those with between five and 50 percent probability of population decline; (2) those with between 50 percent and 90 percent probability of population decline; and (3) those with a greater than 90 percent probability of population decline. TAs that are not listed in each period have less than a five percent probability of population decline. These TAs are not listed to single out particular areas are facing problems, but to note the distribution and the change in numbers over time.

Several things should be noted about these lists. First, the number of TAs appearing in each category increases between the two periods. More TAs are facing population decline in the 2043–2053 decade than in the 2023–2033 decade. This corroborates recent work that has shown similar results (Jackson & Cameron 2017; Jackson 2016). In the 2023–2033 decade 20 TAs face a 90 percent or greater probability of population decline, compared with 26 TAs in the 2043–2053 decade. Granted, these TAs have relatively small populations, representing 12.2 percent of the national population in 2023 (for the 2023–2033 group based on median population size) and 17.2 percent of the national population in 2043 (for the 2043–2053 group).

Second, many TAs increase in the likelihood of population decline over time, shifting from a lower probability group (or unlisted) to a higher probability group. Two TAs in this group (Buller District and Upper Hutt City) are particularly notable in that they switch from a very low probability of population decline in the 2023–2033 decade (less than five percent) to a very high probability of decline in the 2043–2053 decade (greater than 90 percent).

Third, three TAs (Rotorua District, Opotiki District, and South Waikato District) move in the opposite direction, reducing in the probability of population decline between the two decades. These TAs have both relatively young populations and relatively high fertility rates, which may explain this unexpected result.

Finally, the TAs on the list are mostly (but not exclusively) rural and peripheral areas. With the exception of Wellington, the main centres do not make an appearance anywhere on the list. As population decline is projected to be an increasing, and increasingly likely, feature of rural and peripheral New Zealand, population will concentrate further in the main urban centres. For instance, based on median projections Auckland city is projected to grow from 33.6 percent of the total population in 2013 to 40.2 percent in 2053.

Conclusion

This article posed the question: "Is population decline inevitable for New Zealand's rural and peripheral areas?" The answer is clearly 'no'. I have demonstrated that fewer than one-third of TAs are projected to experience near-certain decline, which may be a high or a low proportion, depending on one's perspective. However, demography is clearly not destiny. In a few TAs, the probability of population decline reduces over time. Those TAs tend to have relatively youthful populations and relatively high fertility rates, neither of which are necessarily replicable for policy-makers in other areas.

This presents a clear challenge for policy-makers in rural and peripheral areas that are facing near-certain decline. As explained by Jackson and Cameron (2017), migration is no panacea for these areas – the number of migrants required to reverse population decline that is driven in large part by ageing rural populations is simply too great. Moreover, as Jackson and Cameron (2017) note, migrants eventually add to the problem of an ageing population in declining areas. A recent Maxim Institute report outlines the case for 'accepting and adapting' to depopulation (Wood 2017), and this approach would seem to be most suitable in a lot of rural and peripheral areas (see also McMillan 2016). Creative ways will need to be found to adapt to a declining rating base, to ensure that a minimum level of services is available to remaining residents.

The analysis presented here has several limitations. The model is still under further development, particularly in terms of the projection of international migration (Cameron & Poot 2016). Future developments and improvements are likely to change the projections presented here. The model can capture parameter uncertainty and parametric variability, but cannot adequately deal with model uncertainty. Uncertainty about the optimal model to use for population projections will persist, and provides good reason for Statistics New Zealand to not be the sole provider of subnational population projections in New Zealand. Where the Statistics New Zealand and other projections provide similar results, this should provide additional confidence in their validity, and where they diverge, we should consider the projections to be somewhat more uncertain.

In future research, my collaborators and I will look at the factors associated with a high (or low) probability of population decline, to attempt to identify the lead indicators of the decline. This will build on work based on Statistics New Zealand projections by Jackson (2016). Developing a better understanding of the lead indicators of population decline will enable decision-makers to better anticipate the resulting changes in the population.

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