How accurate are population estimates and projections?

An evaluation of Statistics New Zealand population estimates and projections, 1996–2013

Citation

Statistics New Zealand (2016). *How accurate are population estimates and projections? An evaluation of Statistics New Zealand population estimates and projections, 1996–2013.* Retrieved from www.stats.govt.nz.

ISBN 978-0-908350-66-7 (online)

Published in September 2016 by

Statistics New Zealand

Tatauranga Aotearoa

Wellington, New Zealand

Republished in June 2023 for a correction to Table 8.6 by

Stats NZ

Tatauranga Aotearoa

Acknowledgement

The report was authored by Kim Dunstan, Kate Peterssen, and Bridget Snodgrass of the Population Statistics Unit.

Contact

Statistics New Zealand Information Centre: info@stats.govt.nz

Phone toll-free 0508 525 525

Phone international +64 4 931 4610

www.stats.govt.nz

Contents

List of tables and figures

List of tables

List of figures

1 Purpose and overview

Purpose

How accurate are population estimates and projections? An evaluation of Statistics New Zealand's population estimates and projections, 1996–2013 evaluates the accuracy of recent national and subnational population estimates and projections. The report focuses on estimates and projections of the total population produced and published since 1996, although earlier projections are included where practicable.

This report is designed to help customers understand the accuracy of Statistics NZ's population estimates and projections relative to observed populations, the reasons for inaccuracies, and discusses current developments that may improve accuracy.

Overview

The distinction between estimates and projections is usually that estimates are for dates in the past while projections are for dates in the future. As a result, estimates typically use recorded data on births, deaths, and migration. In contrast, projections typically involve assumptions about future births, deaths, and migration (or the underlying rates) to indicate likely and possible changes in the future size and structure of the population.

Customers are generally interested in the most up-to-date estimates and projections. However, many also seek to understand how accurate estimates and projections **have** been, partly to understand how accurate current estimates and projections **may** be. Assessing past accuracy can be useful in indicating the inherent uncertainty in estimates and projections, and how that uncertainty varies across time, geographic areas, and age groups.

Producers of estimates and projections focus on the ongoing production of quality, timely, and cost-effective information. However, assessing past accuracy can be valuable to understand the strengths and limitations of the methods, and of the estimates and projections themselves across different dimensions.

This report builds on and consolidates results published in *How accurate are population projections? An evaluation of Statistics New Zealand population projections, 1991–2006* (Statistics NZ, 2008). An evaluation of population estimates is included for the first time; this updated report extends the analysis to include the latest 2006–13 intercensal period.

Given space constraints, only a summary analysis is presented here on the accuracy of these population estimates and projections. This includes a limited analysis of the estimates and projections by age.

Evaluations of other Statistics NZ demographic estimates and projections – ethnic populations, families, households and labour force – are not included here. In addition to space constraints, their exclusion is partly because measuring these groups is further complicated by non-demographic factors, such as changes in ethnic definition, identification, and measurement.

Quality dimensions

Most national statistical organisations provide guidelines and discussion of quality dimensions as they relate to statistics (eg Statistics NZ, 2007; Australian Bureau of Statistics, 2009; Office of National Statistics, 2013; Statistics Canada, 2002).

These quality dimensions provide a useful framework for evaluating the usefulness of population estimates and projections.

- **Accuracy** – How do the estimated and projected trends compare with what is observed? Do the estimates and projections adequately illustrate changing demographic patterns?
- **Relevance** – Do the estimates and projections cover the necessary geographic areas, demographic characteristics (eg age, sex, ethnicity), and time periods required by different customers? Are the estimates and projections produced to satisfy the expectations and aspirations of individuals or groups, or are they based on an objective assessment of demographic trends?
- **Timeliness** – Are the estimates and projections updated and available when they are needed?
- **Coherence** – Is the choice of methods, data, and assumptions consistent with accepted practices and do they account for the relevant factors? Are the estimate and projection results plausible given known constraints and limitations?
- **Accessibility** – Is the information readily available to everyone? Are there costs to access?
- **Interpretability** – Is the information about the estimates and projections (eg methods, assumptions, results) available, understandable, and even replicable? Do the estimates and projections provide measures of uncertainty?

Despite these diverse criteria, it is the accuracy of estimates and projections that is most-often questioned.

Structure of this report: a guide for readers

In helping to understand the accuracy of Statistics NZ's estimates and projections, the following questions are covered.

1. How accurate have past estimates and projections been?
2. What types of geographic areas are better/worse estimated and projected?
3. Which components of population change (births, deaths, net migration) contribute most to inaccuracy?
4. How does accuracy vary by geographic area (eg national, regional, territorial authority areas, area units)?
5. How does accuracy vary by age group?
6. Do updated projections within an intercensal period improve an initial set?
7. Is estimation and projection accuracy improving over time?
8. Is past accuracy any indication of future accuracy?
9. What methodological changes might be considered as a result of this evaluation?

The report has nine chapters.

Chapter 2 (**Summary**) summarises the main findings. Chapter 3 (**Estimates and projections in context**) provides context for interpreting accuracy, and details the estimates and projections available for evaluation. Chapter 4 (**Measures of accuracy**) briefly outlines the different measures of accuracy used in this report.

The main analysis of accuracy is presented in chapters 5 to 8.

- **Accuracy of New Zealand estimates** evaluates accuracy at the national level and by age group.
- **Accuracy of subnational estimates** evaluates accuracy at an increasing level of geographic detail – covering regional council (RC) areas, territorial authority (TA) areas, Auckland local board areas (ALBAs), and area units. Analysis of estimates by age group are also presented.
- **Accuracy of New Zealand projections** evaluates accuracy at the national level, including historical projections from the 1950s, the components of change from the 1990s, and by age group.

- **Accuracy of subnational projections** evaluates accuracy at an increasing level of geographic detail covering RC areas, TA areas, ALBAs, and area units. Analysis of projections by age group are also presented.

Chapter 9 (**Discussion and future work**) discusses the analysis for the key findings and outlines prospects for future work.

Given the technical nature of the report, a **Glossary and abbreviations** is provided.

Additional detailed figures are included in:

- Appendix 1: Relative error of projections by average annual population change, territorial authority and Auckland local board areas, 1996–2011
- Appendix 2: Relative error of projections by average annual population change, area units with 100+ population, 1996–2011

See **Accuracy of estimated and projected populations 1996–2013** (interactive Excel file) under 'Available files'. It compares estimated (and projected) population change with observed population change – for all regional council, territorial authority, and Auckland local board areas.

2 Summary

Information about the report

This report assesses three sets of population **estimates** published since 1996 against population benchmarks in 2001, 2006, and 2013 (ie for three intercensal periods 1996–2001, 2001–06, and 2006–13). Assessments are made for:

- New Zealand, 16 regional council (RC) areas, 67 territorial authority (TA) areas, and 21 Auckland local board areas (ALBAs)
- area units: 1,775 for 1996–2001, 1,860 for 2001–06, and 1,927 for 2006–13.

This report assesses population **projections** published since 1991 against population benchmarks in 1996, 2001, 2006, and 2011. Assessments are made of:

- eight sets of New Zealand population projections
- seven sets of RC and TA area population projections
- six sets of area unit population projections
- six sets of ALBA population projections (largely derived retrospectively from area unit population projections).

General findings

- Estimates and projections for larger geographic areas have smaller relative errors than those for smaller geographic areas. Estimate and projection uncertainty therefore increases as geographic size decreases.
- For both estimates and projections, areas with the largest relative errors are generally those experiencing the most-rapid population change (either increase or decrease) and/or those experiencing significant swings in net migration. The pattern is more pronounced for projections (over multiple periods) than estimates.
- It is difficult to conclude whether estimate and projection accuracy is increasing for more-recent estimates and projections. This is because accuracy is partly a function of the demographic variability of different periods, and because short-term accuracy may differ from long-term accuracy (for projections).
- The intercensal projections update, produced two years after the first set of projections, is generally more accurate than the first set. This applies to area unit population projections and projections at higher geographic levels.
- Historical projections have under-projected and over-projected the population at different times. Focusing on the 1991–2011 period, medium (mid-range) projections tended to under-project the population of geographic areas in New Zealand. However, the future direction of inaccuracy of the most-recently published projections is not inevitable, as projection assumptions are revised with each set of projections.
- Most regions, TA areas, and ALBAs are both under-estimated and over-estimated at different times.
- Most regions, TA areas, and ALBAs are both under-projected and over-projected at different times.
- Projections of deaths are more accurate than projections of births, while (net) migration is the most-difficult component to either project, or for assumption formulation.

- Projection accuracy generally decreases as the period from the base (starting point) increases. For example, relative errors tend to be higher after 10 years than after 5, and after 15 years than after 10.
- The observed inaccuracies in estimates and projections cannot be attributed to one particular factor. However, the external migration component is likely to play an important role.
  - In population estimates, measuring external migration is important. The 'permanent and long-term' migration measure (based largely on passengers' stated travel intentions or stated durations of stay/absence), has tended to understate the contribution of net migration to New Zealand's population change, particularly during 2001–06.
  - In population projections, the volatility of New Zealand's external migration balance is also important. Migration assumptions beyond the short-term (five years) cannot realistically anticipate the precise timing of peaks and troughs. As a result, 1991–96 and 2001–06 had relatively high net migration and areas were generally under-projected by the medium projection. In contrast, 1996–2001 had relatively low net migration and geographic areas were generally over-projected by the medium projection. The most-recent period, 2006–11, had more-average net migration and areas were generally more accurately projected.
- The nature of the top-down approach, where national estimates and projections are prepared before subnational estimates and projections, means that subnational accuracy is conditional on national accuracy.
- Females are generally under-estimated and males over-estimated, relative to each other.
- For estimates by age, accuracy is generally highest for the youngest (0–14 years) and middle adult ages (30–84). Accuracy for the young adult ages (15–29 years) and oldest ages (85+) is lower, on average, reflecting fluctuations in migration and small population numbers, respectively.
- For projections by age, accuracy is generally highest for the younger (5–14 years) and middle adult ages (30–84). Accuracy is lower, on average, for the:
  - youngest ages (0–4 years) reflecting fluctuations in births
  - young adult ages (15–29) reflecting fluctuations in migration
  - oldest ages (85+) reflecting small population numbers combined with mortality assumptions.

Detailed findings

Estimates

- For 1996–2001, 2001–06, and 2006–13 combined, absolute relative errors averaged 0.7 percent for New Zealand. The 2001–06 period had the highest relative error (1.1 percent).
- For 1996–2001, 2001–06, and 2006–13 combined, absolute relative errors were under 5 percent for all regions.
- For 1996–2001, 2001–06, and 2006–13 combined, absolute relative errors were under 5 percent for 89 percent of TA areas, and under 10 percent for 98 percent of TA areas.
- For 1996–2001, 2001–06, and 2006–13 combined, absolute relative errors were under 5 percent for 83 percent of ALBAs, and under 10 percent for 97 percent of ALBAs.

- For 1996–2001, 2001–06, and 2006–13 combined, absolute relative errors were under 5 percent for 54 percent of area units, and under 10 percent for 80 percent of area units.

Projections

- For the 1991-base, 1996-base, 2001-base, and 2006-base medium projections combined, absolute relative errors averaged 0.7 percent for New Zealand after five years.
- For the 1991-base, 1996-base, 2001-base, and 2006-base medium projections combined, absolute relative errors were under 5 percent for 98 percent of RC areas after five years, and under 10 percent for all regions after five years.
- For the 1991-base, 1996-base, 2001-base, and 2006-base medium projections combined, absolute relative errors were under 5 percent for 89 percent of for TA areas after five years, and under 10 percent for 98 percent of these areas after five years.
- For the 1996-base, 2001-base, and 2006-base medium projections combined, absolute relative errors were under 5 percent for 82 percent of ALBAs after five years, and under 10 percent for 97 percent of these areas after five years.
- For the 1991-base, 1996-base, 2001-base, and 2006-base medium projections combined, absolute relative errors were under 5 percent for 65 percent of area units (with populations of 100+) after five years, and under 10 percent for 87 percent of these areas after five years.
- For the 1991-base, 1996-base, and 2001-base medium projections combined, absolute relative errors were under 5 percent for 53 percent of TA areas after 10 years, and under 10 percent for 81 percent of these areas after 10 years.
- For the 1991-base and 1996-base medium projections combined, absolute relative errors were under 5 percent for 36 percent of TA areas after 15 years, and under 10 percent for 67 percent of these areas after 15 years.
- For the 1991-base medium projections, absolute relative errors were under 5 percent for 25 percent of TA areas after 20 years, and under 10 percent for 48 percent of these areas after 20 years.

3 Estimates and projections in context

Before presenting the results of the evaluation, it is important to put some context around the population estimates and projections. Context relates to the inherent nature, role, and limitations of estimates and projections; aspects of accuracy; an overview of Statistics NZ's estimates and projection methodology; and availability of estimates and projections for evaluation.

International assessments of accuracy

One might expect assessments of estimates and projection accuracy to be routine among national statistical organisations. However, if so, few are published, perhaps reflecting that retrospective analyses inevitably takes lower priority than producing new estimates and projections, or methodological work geared to this imperative.

Assessments of estimates' accuracy include those relating to Australia (Howe, 1998), United Kingdom (Lunn et al, 1998; Smith & Tayman, 2003), and United States (Harper et al, 2002). Assessments of projection accuracy include those for Australia (Bell & Skinner, 1992; Wilson, 2007; Wilson & Rowe, 2011; Chomik, 2015), Canada (Dion & Galbraith, 2015), United Kingdom (Shaw, 2007; Keilman, 2007; ONS, 2015a, 2015b), and United States (Ching-li Wang, 2002).

Why Statistics NZ produces estimates and projections

Statistics NZ produces population estimates to inform New Zealanders about how our population is changing after, or in between, each Census of Population and Dwellings. The rationale for producing population projections may be less clear.

Statistics NZ produces a range of demographic projections, including projections of the population, ethnic populations, families, households, and labour force, at a variety of geographic levels. Statistics NZ has produced demographic projections for New Zealand since the early 1950s. In the mid-1970s it began projecting the population of subnational areas, a role that was previously undertaken by the Ministry of Works.

There are several reasons why national statistical organisations produce population projections. First, as a producer of census data and population estimates, population projections are a logical and complementary extension. Collectively, these population data give information about past, current, and potential future population changes. In turn, this allows all New Zealanders to understand how our population is changing and to make well-informed decisions (Statistics NZ, 2012c).

Second is the value of having the independence and integrity of a national statistical organisation producing population projections. There is also the advantage of producing a consistent set of projections for every area of New Zealand – consistency in methods and with national-level projections – rather than a fragmented set of projections produced by, or for, different local authorities. In addition, the internal consistency of the different projections – population, ethnic populations, families, households, and labour force – is highly desirable from a customer's perspective.

Third, New Zealand's population can be projected with more confidence than most other social or economic aspects. Fertility, mortality, and migration patterns have some regularity from year to year. In addition, roughly three-quarters of New Zealand's population in 20 years is already alive, as is half of New Zealand's population in 40 years, and everybody aged 65+ in 60 years. Only deaths and migration can alter the numbers of people already alive. Projections of sub-populations (eg for subnational geographies or ethnic groups) are more uncertain because of the added dynamics of internal migration and inter-ethnic mobility (people changing ethnic identification).

Projections and forecasts

Demographic projections produced by Statistics NZ are not predictions or forecasts. The projections indicate future population and change if the stated assumptions apply over the projection period. Statistics NZ produces a range of alternative projections to illustrate different scenarios. In contrast, a forecast is one prediction of what the population will be at a given date.

Organisations, which include central and local governments, often initiate strategies to avert the population trends implied by the projections. It is therefore illogical to criticise the projections if they do not match actuality, especially when the projections are used to inform those strategies. One role of projections is to enable future changes to be understood and managed, if not averted.

Since projections are based on current policy settings they do not try to anticipate major policy changes. The difference between projections and predictions is provided in an analogy made by the Australian Productivity Commission (2005): someone sees a large boulder on a train track. The **projection** is that there will be a rail disaster and many deaths if the boulder is not moved or the train is not stopped. The **prediction** is that someone will move the boulder, averting the accident. The projection is much more useful for policy formulation and planning.

The value of population projections is therefore less defined by whether or not they match reality, but more about whether they are plausible and useful to customers at the time they are published. Projections form a basis for developing reasonable expectations about the future; help focus attention on potential events, risks, and opportunities; and allow people and policy-makers to plan and make decisions accordingly.

The distinction between projections and forecasts is not necessarily shared by others (eg Alho, 1997; Keilman, 1997) who argue the mid-range projection is inevitably used as a forecast. However, Statistics NZ makes it clear when publishing projections that customers can (and should) make their own judgement as to which projections are most suitable for their purposes – this will not necessarily be the mid-range projection.

Customers' requirement for accuracy

How accurate do population estimates and projections need to be to be 'fit for purpose'? This question applies most to estimates, given the role and nature of projections discussed above. Statistics NZ has considered what 'fit for purpose' means for population estimates in looking at major changes to census (McNally & Bycroft, 2015).

That investigation identified possible quantified quality standards for population estimates that represent customers' needs. The standards build on previous knowledge of key population statistics uses, and reflect consultation with core customers of population statistics. The quality standards are expressed for customers' minimum accuracy requirements – for differing levels of geography and age-group breakdowns. The standards are a benchmark for assessing the strengths and limitations of alternative approaches to producing population statistics.

These possible accuracy standards provide a useful framework for evaluating the accuracy of past population estimates, and reference is made to these standards in the evaluation sections (chapters 5 and 6).

Sources of inaccuracy

Many different factors contribute to the inaccuracy of population estimates and projections.

Estimates

For estimates, the intercensal discrepancy is the net combined effect of factors that include inaccuracies in the:

- census counts at the beginning and end of the period
- adjustments to derive population estimates (from census counts) at the beginning and end of the period
- components of population change (births, deaths, migration) during the period.

Inaccuracies in the census counts can arise during the enumeration or processing phases and affect the coverage or characteristics of the population. This includes non-response, deliberate or inadvertent errors by respondents or collectors, and errors from scanning, numeric and character recognition, imputation, coding, and editing.

Population estimates since 1996 include adjustments for imperfect census coverage (net census undercount), and for residents temporarily overseas on census night. However, these adjustments have uncertainty, especially at a local level, and notably with sampling error in the results of the post-enumeration survey (Bryant et al, forthcoming).

Registered births and deaths have high coverage and timeliness for population estimation. Migration, both external and internal, has larger errors and is the likely source of most intercensal discrepancy. However, even if the components of change (births, deaths, migration) are perfectly estimated after a census, intercensal discrepancy still arises because of inaccuracies in the base (starting) population, or the end population (with which comparisons are made).

Finally, although the base population and components of population change all relate to the resident population, how this population is defined may vary in different collections. More importantly, how people interpret and respond to questions on usual address may differ – the resident population is defined statistically (not in legal terms), and is generally based on a person's self-identified usual address.

- In census statistics, a resident is a person who self-identifies on the census individual form that they usually live in an area (although the census guide notes give further advice where there may be confusion).
- In international travel and migration statistics, a resident is someone who is living in New Zealand for 12 months or more, as determined from arrivals and departures of the person, and/or their intentions (stated on arrival/departure cards).
- In birth registration statistics, the child’s residence is based on the self-identified ‘home address’ of the mother.
- In death registration statistics, the residence of the deceased is based on their ‘usual home address’ as identified by the family and/or funeral director.

Projections

For projections, their accuracy depends on the accuracy of population estimates. Population estimates are the starting point (base) for all population projections. Subsequent post-censal population estimates are then used to inform the projection assumptions. The census-year estimates are also the retrospective benchmark by which the projections are evaluated here.

However, as with estimates, even if the components of change (births, deaths, migration) are perfectly projected after a census, there may still be apparent projection inaccuracy because of inaccuracies in the base population, or in the end population (with which comparisons are made).

Projections are also subject to other sources of inaccuracy not present for estimates. These reflect the fact that projections are estimates of the population in the future.

First, there are inaccuracies in the fertility (birth), mortality (death), and migration assumptions the projections are based on. This is effectively what this paper focuses on evaluating. Note that uncertainty in the coverage and accuracy of data sources and population estimates also affects the estimates of fertility, mortality, and migration from which assumptions are made about future patterns.

Second, there are non-demographic factors the projections cannot anticipate. These are not accounted for in the projections unless they were known when the projections were produced, or are reflected in historical trends (eg in migration data). Examples include: war, catastrophe (eg 2010–11 Canterbury earthquakes), major government decisions (eg Immigration Act 1986, 1987), major business decisions (eg industries opening and closing), and institutional changes (eg in the armed forces, prisons, universities). These factors can significantly influence population dynamics, especially at a local level.

While it is recognised that social, economic, political, and environmental factors influence the demographic factors, modelling the demographic factors when estimating or projecting the population is generally sufficient. The wider factors are implicitly accounted for through their influence on past trends in births, deaths, and migration.

Changing accuracy with time and detail

Projection accuracy in the short-term (ie less than five years) may be different to long-term projection accuracy. For example, short-term fluctuations (in net migration or births) may average out over longer periods. As the projections aim to meet both short-term and long-term planning needs, their accuracy may vary over time.

Similarly, accuracy at an aggregate level can conceal variations at a disaggregated level. Conversely, inaccuracy at an aggregate level can conceal valuable accuracy at a disaggregated level. This is particularly relevant for customers who are interested in projections for specific age groups (eg educational ages, older people). Also, projections of changing age composition, rather than total numbers in an area, are often what is most useful for policy and planning (eg service provision).

Statistics NZ methodology

Top-down approach

Statistics NZ adopts a 'top-down' approach to producing both estimates and projections. This means that estimates/projections are first completed at the national level. These subsequently serve as a constraint for estimates/projections at the territorial authority (TA) level. In turn, these provide a constraint for smaller area estimates/projections (eg area units).

For projections, the top-down constraints apply only to the medium (mid-range) projection. Low and high growth projections for geographic areas are alternative plausible projections either side of the medium (mid-range) projection, but they do not sum to any constraint.

This approach potentially means that population trends in smaller geographic areas are not immediately accounted for in population estimates/projections for larger geographic areas. However, they may be implicitly accounted for through demographic trends in the larger geographic areas or when feedback is incorporated in subsequent estimates/projections.

The advantages of the top-down approach include publishing higher geographic area estimates/projections more quickly, and avoiding implausible estimates/projections at higher geographic levels. However, the accuracy of subnational population estimates/projections is affected by the accuracy of those at the national level.

Cohort component method

All population estimates and projections produced by Statistics NZ use the cohort component method. The method recognises that fundamentally only three factors can change the population: births (fertility), deaths (mortality), and migration:

$$P_t = P_{t-1} + B - D + NM$$

P_t population at end of period

P_{t-1} population at start of period

B births during period

D deaths during period

NM net migration (arrivals – departures) during period

The essential difference between estimates and projections is the use of recorded (historical) data for estimates, and assumptions (about the future) for projections. For estimates, the base population is rolled forward by calculating the effect of recorded deaths and migration within each age-sex group (or cohort). New birth cohorts are based on recorded births.

In projections, the base population forward by calculating the effect of deaths and migration within each age-sex group, according to specified mortality and migration assumptions. New birth cohorts are generated by applying specified fertility assumptions to the female population of childbearing age.

The exact methods also differ between national and subnational geographies. See Statistics New Zealand (nd a, nd c) for a fuller description of methods.

Simplified models

Models, including population projection models, are simplifications of a complex real world. Traditionally, Statistics NZ simplifies the fertility, mortality, and migration assumptions. This includes assuming smooth assumption trajectories over time to represent long-term average behaviour. It also includes setting assumptions that are rounded to a convenient level (eg rounding net migration to thousands at the national level).

Even with stochastic projections, where the input assumptions and resulting projections are allowed to vary randomly according to specified probability distributions, the frequently cited ‘median’ projection is a summary statistic of the multiple simulations.

The projections are therefore a simplification of a complex reality. They indicate overall trends and are generally not designed to indicate specific annual variations. Without simplification, the projections risk conveying spurious precision for both the input assumptions and output results.

Alternative projections

Statistics NZ always provides a range of alternative projections or scenarios. This is partly to indicate the uncertainty in projection outcomes, partly to indicate the significance of different projection assumptions for projection results, and partly to provide different projection scenarios for different customers.

For subnational population projections, Statistics NZ typically produces ‘low’, ‘medium’, and ‘high’ projections. These descriptors relate to population growth rates and population size but not necessarily to other population characteristics (eg births, deaths, median age, dependency ratios). This is one reason why Statistics NZ has been developing stochastic projections, which better convey the uncertainty in all projected population characteristics.

Together these projections indicate a range of possible and plausible outcomes, but they do not encompass all possibilities. At the time of publication, Statistics NZ considers the medium (mid-range) projection as suitable for assessing future population changes. However, customers are always advised to make their own judgement on which projections best suit their purposes.

Recent estimates and projections

Focus of evaluation

This evaluation aims to investigate the accuracy of the most-recent Statistics NZ population estimates and projections – those produced since the 1996 Census. This recent focus reflects practical issues around changes in population concepts, the availability of earlier estimates/projection data, and boundary changes at a subnational level.

Population concepts

From 1996, all population estimates and projections use the **resident** population concept. That is, they are a measure of the population that **usually lives** in an area.

Before 1996, most estimates and projections used the **de facto** population concept. That is, they were a measure of the population **present** in an area at a given date, including overseas visitors and those from elsewhere in New Zealand, and excluding New Zealand residents temporarily overseas. De facto population estimates made no allowance for net census undercount.

Population estimates from 1996 are derived from census usually resident population counts but also include allowances for New Zealand residents not counted by the census – notably, residents missed by the census (net census undercount or NCU) and residents temporarily overseas (RTOs) at census time.

Based on international travel and migration data since 1996, about 85 percent of RTOs return to New Zealand within one month of departure, and about 95 percent return within two months of departure. To measure the population usually living in New Zealand, and given the purposes for which population estimates are used, it makes sense to include RTOs in the 'estimated resident population' (ERP).

To measure the accuracy of population estimates/projections, the ERP provides the best and most valid comparison because the differential effects of NCU and RTOs over time are removed (in theory). If NCU and RTOs are consistent over time, then census counts give a valid comparison. However, both NCU and RTOs have increased in absolute terms over recent years (Statistics NZ, 2014a, table 6, page 25). This report also describes the ERP's derivation and associated adjustments.

Historical availability

For subnational population measures, the local government reorganisation that took effect on 1 November 1989 caused significant boundary changes. This makes comparing pre-1991 projections with recent population estimates or census counts problematic. For the 1991-base area unit population projections, the detailed historical datasets are unavailable so no evaluation is possible.

Given customer interest in RC and TA area population projections, the 1991-base projections published in January 1993 are evaluated in this report. Since these projections had the 'census usually resident population count' at 5 March 1991 as their base, the most appropriate comparison for them is with changes in the census usually resident population count between reference years. However, comparisons with the 1991-base projections will not account for different patterns of undercount and RTOs from census to census, unlike comparisons with ERP. For this reason, customers should take extra care when interpreting the 1991-base projections' accuracy.

Between the 1991 and 2013 Censuses, Statistics NZ published nine sets of population projections for New Zealand (see table 3.1); and eight sets of population projections for RC and TA areas, and seven sets of population projections for area units (table 3.2).

Table 3.1

Most-recent national population projections published by Statistics NZ
1992–2015

Base population	Projection horizon	Publication date
Estimated de facto population at 31 March 1991	2031	Feb 1992
Estimated de facto population at 31 March 1994	2031	Dec 1994
Estimated resident population at 30 June 1996	2051	Oct 1997
Estimated resident population at 30 June 1999	2051	Feb 2000
Estimated resident population at 30 June 2001	2051	Oct 2002
Estimated resident population at 30 June 2004	2051	Dec 2004
Estimated resident population at 30 June 2006	2061	Oct 2007
Estimated resident population at 30 June 2009	2061	Oct 2009
Estimated resident population at 30 June 2011(1)	2061	Jul 2012
Estimated resident population at 30 June 2014(1)	2068	Nov 2014

1. These projections are not evaluated in this report because they cannot be compared with any of the 1996–2011 populations.

Source: Statistics New Zealand

Table 3.2

Most-recent subnational population projections published by Statistics NZ
1992–2015

Base population	Projection horizon	Publication date (RC and TA areas)	Completion[1] date (area units)
Census usually resident population count at 5 March 1991	2016	Jan 1993	Dec 1995[2]
Estimated resident population at 30 June 1996	2021	Oct 1997	Dec 1997
Estimated resident population at 30 June 1996	2021	May 2000	May 2000
Estimated resident population at 30 June 2001	2021	Nov 2002	May 2003
Estimated resident population at 30 June 2001	2021	Feb 2005	Jun 2005
Estimated resident population at 30 June 2006	2031	Dec 2007	Oct 2008
Estimated resident population at 30 June 2006	2031	Feb 2010	Oct 2010
Estimated resident population at 30 June 2006[3]	2031	Oct 2012	Dec 2012[4]
Estimated resident population at 30 June 2013[5]	2043	Feb 2015	Sep 2015

1. Refers to final month of completion for projections since 2006 that were released progressively over several months. Before 2006, these projections were not published as official projections.

2. These projections are not evaluated in this report because the original datasets are not available.

3. These projections are evaluated in this report despite being published after the 2011 comparison point, because they were published before 2013 Census results were available.

4. This update was limited to all 188 area units in Christchurch city, Waimakariri district, and Selwyn district which were most affected by the 2010–11 Canterbury earthquakes.

5. These projections are not evaluated in this report because they cannot be compared with any of the 1996–2011 populations.

Source: Statistics New Zealand

Geographic areas and boundaries

Estimates and projections are always derived and published for the geographic boundaries existing at the time of publication. However, to help customers understand accuracy for current areas, this evaluation of accuracy focuses on the latest geographic boundaries. That is, the boundaries existing at 1 January 2016.

Estimates and projections of the population usually living in the following geographic areas are assessed here:

- **New Zealand** – ‘Low’, ‘medium’, and ‘high’ are not terms that describe different national population projections. The low, medium, and high figures for New Zealand used in this report are derived from selected national population projections that are broadly comparable with the low, medium, and high projections for subnational areas.

- **Regional council areas (regions)** – There are 16 RC areas, as there were when constituted in 1989, although they have had several boundary changes since then.
- **Territorial authority areas (cities and districts)** – Through amalgamation, the number of TAs has reduced from 74 in 1989 to 73 in 2006, then to 67 based on 2016 boundaries.
- **Auckland local board areas** (ALBAs) – Given the size of Auckland region/city, which accounts for over one-third of New Zealand's population, it is necessary to provide some disaggregation intermediate between the region/city and area units. ALBAs provide this. They came into existence on 1 November 2010. There are 21 ALBAs based on 2016 boundaries.

  Historical 'medium' projections for ALBAs can be approximated by aggregating area unit projections, even though numerous area units are split between ALBAs. However, it is impractical to derive 'low' and 'high' projections for ALBAs using this approach, as these projections are plausible for the geography at which they are designed, but are unlikely to remain plausible after aggregating to higher geographies.
- **Area units (suburbs)** – The number of areas units has increased over time, largely in response to population and household growth. There were 1,775 area units at the 1996 Census, 1,860 at the 2001 Census, 1,927 at the 2006 Census, and 2,020 at the 2013 Census.

  In practice, many area units have zero or small populations, which affects the calculation of accuracy measures. In particular, relative errors become misleadingly large for areas with very small populations, and can distort measures of accuracy for area units overall. A pragmatic approach is to exclude area units with populations under 100 when evaluating relative errors.

Cancellation of 2011 Census

The cancellation of the 2011 Census due to the Canterbury earthquakes complicated evaluations of accuracy. Instead of the typical five-year gap between census dates, the census was held in 2013, seven years after the 2006 Census.

For evaluating the estimates' accuracy, the seven-year gap presents no problems, as both national and subnational population estimates are derived and published for each year.

For projections, there are two options to handle the irregular spacing. First, projections could be compared with estimates for 2013. Theoretically, the estimates are at their most accurate in 2013. For national population projections, the evaluation is straightforward as projections for 2013 from each base. For subnational population projections, the evaluation would require using unpublished customised projections (2006-base), or creating 2013 projections by some interpolation between 2011 and 2016 projections (for1991-base, 1996-base, and 2001-base).

Second, projections could be compared with estimates for 2011. Revised national and subnational population estimates are published for 2011. The 2011 ERP is partly an interpolation of final ERPs for 2006 and 2013, but weighted by the estimated components of population change during 2006–13. In theory, the 2011 ERP is not as accurate as the 2013 ERP. However, the 2011 ERP is adequate for evaluation purposes and aligns with the published projections.

The second option has been used in this report – using interpolated estimates as the benchmark rather than creating projections for 2013 by interpolation. This also has the advantage that different projections can be consistently compared over 5 years, 10 years, 15 years, and so on. Future evaluations may use the first option, but using both options would over-complicate this report without adding extra insight.

Published five-year steps and age groups

Statistics NZ's subnational population projections are conventionally derived and published in five-year steps (eg 1996, 2001, 2006, …) and by five-year age groups (0–4, 5–9, … 80–84, 85+). Subnational population projections at one-year intervals and by single-year age groups were often derived but not published, being available only as 'customised' projections. This is because the subnational projection model has focused on indicating trends at the more-aggregated level and not on annual changes or finer age-level changes (which have greater uncertainty). However, all projections from 1996 have the population estimates in a census year as their base – in principle, this is when the population estimates are most accurate.

Even though subnational population estimates are derived and published annually, these estimates are more uncertain (and historically more inaccurate) than national population estimates. This is largely because subnational populations have the added dynamic of internal migration, and there is no direct and comprehensive annual measure of internal migration in New Zealand.

Because subnational population projections are conventionally derived and published in five-year steps, using a non-census year base would also misalign new projections with past projections. This becomes less of an issue if subnational population projections are directly derived and published in one-year steps and by single-year age groups (see 'Discussion and future work' for more comment).

Comparison dates

Following the derivation of ERP at 30 June 2013, using counts from the 2013 Census, four census year ERPs are now available.

Population estimates are simply compared with the final revised ERP at 30 June in 2001, 2006, and 2013.

Population projections are compared with the final revised ERP at 30 June 1996, 2001, 2006, and 2011 (table 3.3). There are two exceptions to this:

1. The 1991-base and 1994-base national population projections are compared with ERPs at 31 March 1996, 2001, 2006, and 2011 – for consistency with the base reference date.
2. The 1991-base subnational population projections are compared with census usually resident population counts in 1996, 2001, 2006, and 2011 for consistency in population measure. As no census counts exist for 2011, these are estimated using a weighted interpolation of the 2006, 2011, and 2013 ERPs.

Evaluation of national and subnational projections published in 2012 are included. These were published after the 30 June 2011 comparison point, but before the 2013 Census. Hence, there is still validity in measuring their accuracy over the 2006–11 period (and beyond if further evaluations are done in future).

Table 3.3

Available comparisons of projections with estimated resident population (ERP)
1996–2011

National population projections	Subnational population projections[1]		Comparison with ERP at 30 June			
	RC and TA areas	Area units	1996	2001	2006	2011
1991-base published Feb 1992	1991-base published Jan 1993	Not available	Yes	Yes	Yes	Yes
1994-base published Dec 1994	Not available	Not available	Yes	Yes	Yes	Yes
1996-base published Oct 1997	1996-base published Oct 1997	1996-base completed Oct 1997	No	Yes	Yes	Yes
1999-base published Feb 2000	1996-base published May 2000	1996-base completed May 2000	No	Yes	Yes	Yes
2001-base published Oct 2002	2001-base published Nov 2002	2001-base completed May 2003	No	No	Yes	Yes
2004-base published Dec 2004	2001-base published Feb 2005	2001-base completed Jun 2005	No	No	Yes	Yes
2006-base published Oct 2007	2006-base published Dec 2007	2006-base completed May 2008	No	No	No	Yes
2009-base published Oct 2009	2006-base published Feb 2010	2006-base completed Apr 2010	No	No	No	Yes
2011-base published Jul 2012	2006-base published Oct 2012	2006-base completed Dec 2012[2]	No	No	No	Yes

1. Auckland local board area projections were published for the first time in Nov 2012 (2006-base). However, they can be derived retrospectively by aggregating area unit projections.

2. This update was limited to area units in Christchurch city, Waimakariri district, and Selwyn district to reflect the impact of the 2010–11Canterbury earthquakes. This comparison includes projections released in 2010 for all other area units.

Source: Statistics New Zealand

4 Measures of accuracy

Several measures are used in this report to evaluate the accuracy of estimated and projected populations relative to observed populations.

Error

Error (E) is the numerical difference between the estimated/projected population and observed population in a given year:

$$E = EP_y - O_y$$

E = error

EP_y = estimated/projected population in year y

O_y = observed population in year y

An E of 500 indicates that a given estimate/projection was 500 higher (over-estimated/projected) compared with the observed population for that year. An E of -500 indicates a given estimate/projection was 500 lower (under-estimated/projected) compared with the observed population for that year.

The observed population is typically the revised population estimate in a census year, incorporating results from that census.

The error or difference between the original and revised census-year population estimates is commonly referred to as ‘intercensal discrepancy’.

Corrected error

The 1996-base estimates and projections were adjusted (upwards) to account for the revision of the 1996-base population estimate in 2002. At the national level, the estimated resident population at 30 June 1996 was revised up by 18,000 (0.5 percent). To account for this revision, a corrected E is calculated (Keilman, 1997):

$$CE = EP_y - O_y - (EP_b - O_b)$$

CE = corrected error

EP_b = original population in base year b

O_b = revised population in base year b

If the aim of the estimates/projections is to measure population change over a given period, then the CE gives a better measure of the accuracy of the estimate/projection, without the conflating effect of a known inaccuracy in the base population estimate.

When calculating corrected errors for age groups, these are done on a birth cohort basis. For example, the corrected error for age group 5–9 years in 2001 corrects for the larger population of age group 0–4 years in 1996; the corrected error for age group 10–14 years in 2001 corrects for the larger population of age group 5–9 years in 1996; and so on.

The correction will not fully account for the effect of inaccuracy in the base population. For example, fertility rates are applied in projections to the female childbearing population to give births. A larger childbearing population would give more births, all other things being equal, so the correction will understate the projected population at the youngest ages. In contrast, survivorship rates are applied in projections to the population to give survivors and deaths. A larger population would give more deaths, all other things being equal, so the correction will overstate the projected population at the oldest ages.

Relative error

Relative error (RE) is the percentage difference between the estimated/projected population (corrected if necessary, as above) and observed population in a given year, relative to the observed population:

$$RE = (\frac{EP_y - O_y}{O_y}) \times 100$$

RE = relative error (percent)

A RE of 5 percent indicates that a given estimate/projection was 5 percent higher (over-estimated/projected) than the observed population for that year. A RE of -5 percent indicates a given estimate/projection was 5 percent lower (under-estimated/projected) than the observed population for that year.

RE is a standard approach to assessing accuracy (eg Bell & Skinner, 1992; Keilman, 1997, 2007; Wilson, 2007) although other measures can be used (eg Swanson et al, 2000). The advantage of RE over E is that RE facilitates comparisons between periods of different length, between areas of different population size, and between different population measures.

Mean and median relative error

Where multiple estimates/projections are being evaluated, such as those for regions, it can be useful to calculate the $mean\ RE$:

$$mean\ RE = \sum_{1}^{n} (\frac{EP_y - O_y}{O_y}) \times \frac{100}{n}$$

$mean\ RE$ = mean relative error (percent)

n = number of estimates/projections (eg number of areas)

Alternatively, the $median\ RE$ is the value where half the estimates/projections (eg of regions) are above, and half are below.

Absolute relative error

Absolute relative error (ARE) is the percentage difference, irrespective of sign (positive or negative), between the estimated/projected population and the observed population in a given year, relative to the observed population:

$$ARE = |\frac{EP_y - O_y}{O_y}| \times \frac{100}{n}$$

ARE = absolute relative error (percent)

ARE indicates the extent of inaccuracy, but not the direction (bias) of that inaccuracy.

Mean and median absolute relative error

Again, where multiple estimates/projections are being evaluated, such as those for regions, it can be useful to calculate the $mean\ ARE$:

$$mean\ ARE = \sum_{1}^{n} \left|\frac{EP_y - O_y}{O_y}\right| \times \frac{100}{n}$$

$mean\ ARE$ = mean absolute relative error (percent)

Alternatively, the $median\ ARE$ is the value where half the estimates/projections (eg of regions) are above, and half are below.

Average annual population change

Average annual population change ($AAPC$) is compared directly between the estimated/projected populations (low, medium, and high) and observed populations. $AAPC$ is calculated as a constant annual rate of population change over the stated period (ie assuming geometric growth rates to allow for compounding growth):

$$AAPC = [(\frac{P_2}{P_1})^{\frac{1}{y}} - 1] \times 100$$

$AAPC$ = average annual population change (percent)

P_2 = population at the end of the period

P_1 = population at the beginning of the period

y = number of years from the beginning to the end of the period

As with REs, the advantage of $AAPC$ over numerical changes is that $AAPC$ facilitates comparisons between periods of different length, between areas of different population size, and between different population measures.

5 Accuracy of New Zealand estimates

This chapter reviews the accuracy of national (New Zealand) population estimates, including estimates of the total population and age groups.

Total population

The national population estimates had an average absolute relative error (ARE) of 0.7 percent over the three intercensal periods (see table 5.1, figure 5.1). A 1.0 percent threshold corresponds to a possible accuracy standard for these estimates (McNally & Bycroft, 2015). In the 2001–06 period (ie for the 2001-base estimates in 2006), the ARE was slightly higher at 1.1 percent. This higher error probably reflects the relatively high net migration during 2001–06 and its contribution to population change being under-estimated by the conventional ‘permanent and long-term’ (PLT) migration statistics, although several factors potentially contributed to the inaccuracy (see Sources of inaccuracy: Estimates).

The 1996-base estimates in 2001, as published, were actually an under-estimate of 30,400 or 0.8 percent. However, allowing for the rebasing of the 1996 population for a revised net census undercount reduces this under-estimate to 12,500 or 0.3 percent (excluding revisions made to estimated natural increase in 1996–2001).

The relative errors (REs) for the different sexes at national level ranged from -1.6 percent to 1.3 percent, with males generally being over-estimated and females generally being under-estimated. This male-female imbalance may reflect limitations of the PLT migration statistics, although we cannot dismiss other sources of inaccuracy.

Table 5.1

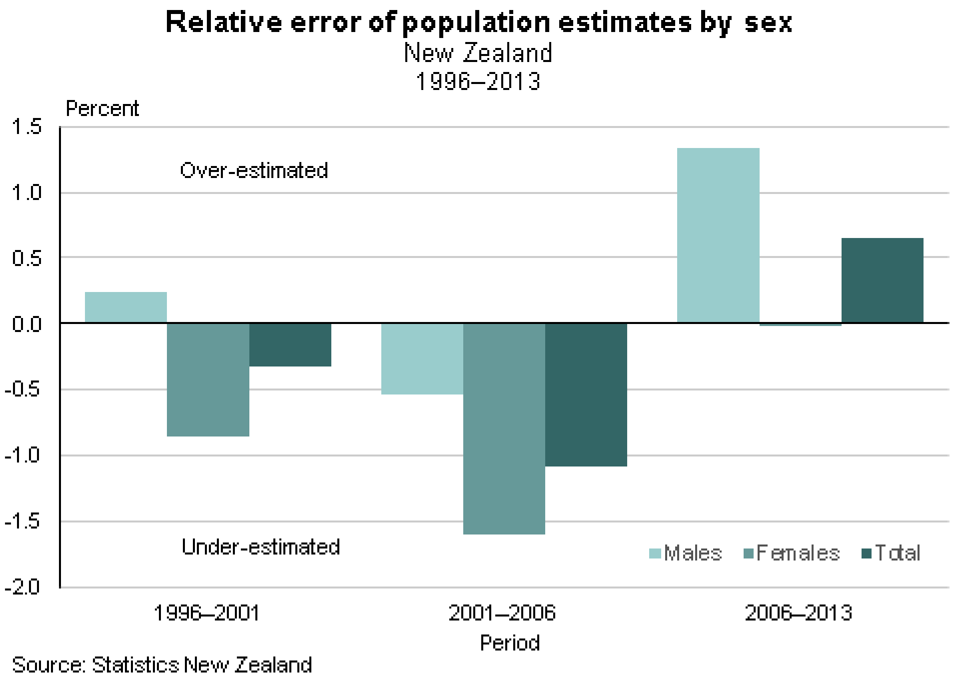
Error and relative error of population estimates for New Zealand
By sex
1996–2013

Period	Error (000)			Relative error (%)		
	Male	Female	Total	Male	Female	Total
1996–2001	4.5	-17.0	-12.5	0.2	-0.9	-0.3
2001–2006	-10.8	-34.3	-45.1	-0.5	-1.6	-1.1
2006–2013	29.1	-0.1	29.0	1.3	0.0	0.7

Note: Shaded values are those not meeting the possible accuracy standards. The possible accuracy standard for total population is used here for males and females.

Source: Statistics New Zealand

Figure 5.1



Age groups

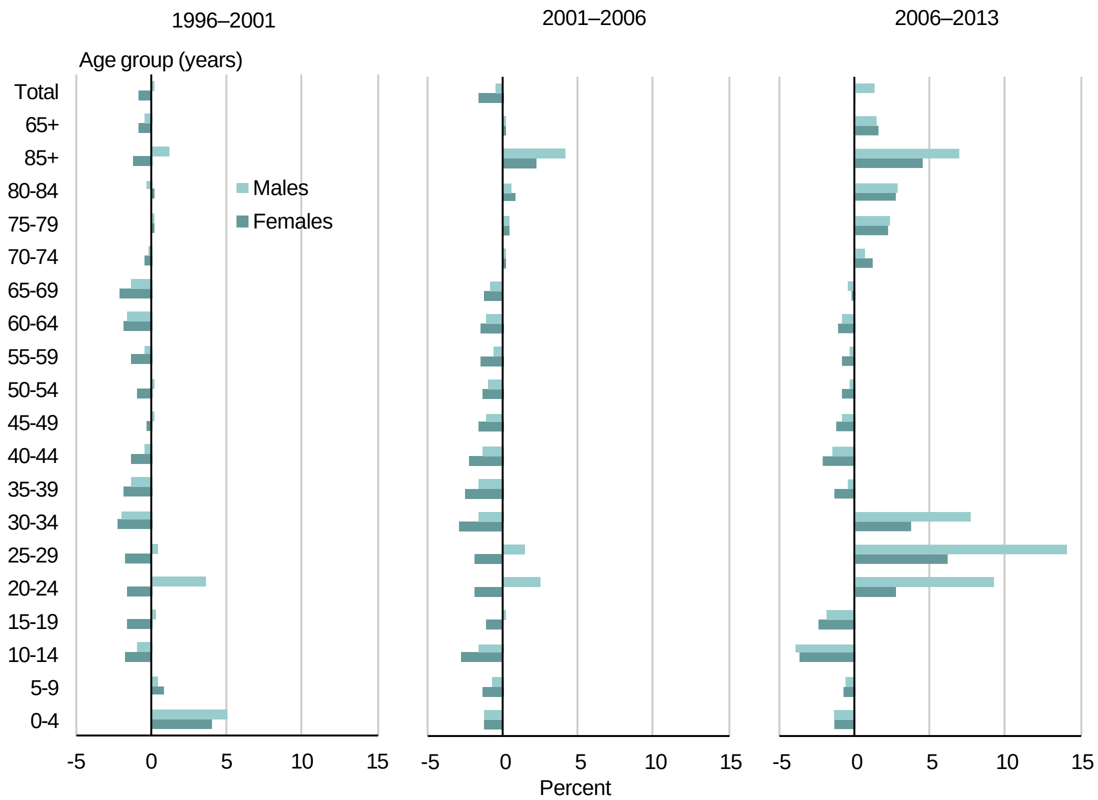
For both females and males, the AREs tended to be largest for the 0–4, 10–14, 25–29, and 30–34-year age groups, as well as the 20–24 and 85+ age groups for males (figure 5.2). REs were significantly higher for some age groups in the longer 2006–13 period, despite the overall RE for total population being lower than in the 2001–06 period.

Figure 5.2

Relative error of population estimates by five-year age group and sex

New Zealand

1996–2013



Source: Statistics New Zealand

Possible accuracy standards for age groups at the national level are "90 percent of all national population estimates by five-year age group and sex are within 3 percent relative error, and all are within 10 percent" (McNally & Bycroft, 2015). Using this as a guide, the longer 2006–13 period was less accurate than the preceding two intercensal periods and does not satisfy either standard (table 5.2).

Table 5.2

Percentage of absolute relative errors for New Zealand population estimates within possible accuracy standards

36 five-year age-sex groups

1996–2013

Period	Percent of absolute relative error under:	
	3 percent	10 percent
1996–2001	92	100
2001–2006	97	100
2006–2013	75	97

Note: Shaded values are those not meeting the possible accuracy standards.

Source: Statistics New Zealand

6 Accuracy of subnational estimates

This chapter reviews the accuracy of subnational population estimates, namely estimates of the total population for regional council (RC) areas (regions), territorial authority (TA) areas (cities and districts), Auckland local board areas (ALBAs), and area units ('suburbs'). Estimates by age group are then reviewed for larger subnational areas.

See **Accuracy of estimated and projected populations 1996–2013** (interactive Excel file) under 'Available files'. It compares estimated (and projected) population change with observed population change – for all RC and TA areas, and ALBAs.

Regions

Similar to the results for the national population estimates, the mean and median absolute relative errors for regions were higher for the 2001–06 period (see table 6.1, figure 6.1). This higher error probably reflects the relatively high net migration during 2001–06 and its contribution to population change being under-estimated by the conventional PLT migration statistics, although several factors potentially contributed to the inaccuracy (see Sources of inaccuracy: Estimates). The mean and median absolute errors for the 2006–13 period were higher than the preceding five-year periods, reflecting population growth in most regions, although the mean and median absolute relative errors were similar.

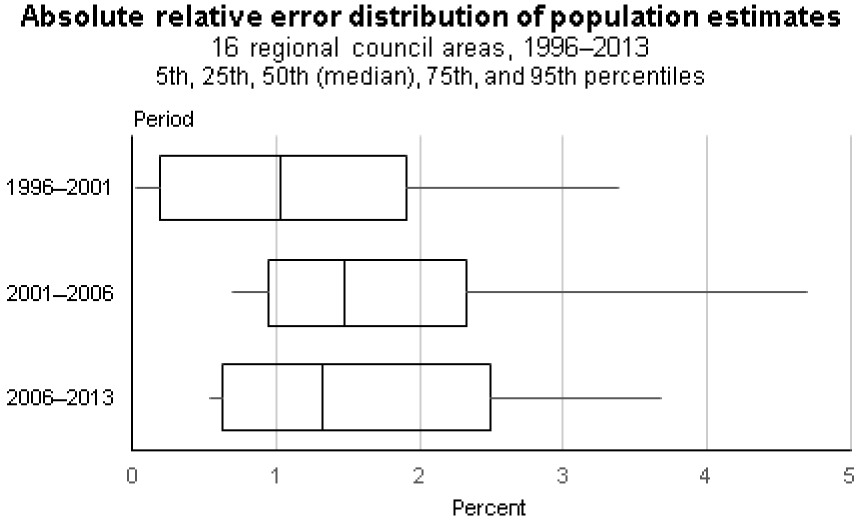
Table 6.1

Mean and median absolute errors and absolute relative errors of population estimates
16 regional council areas
1996–2013

Period	Mean absolute error	Median absolute error	Mean absolute relative error (%)	Median absolute relative error (%)
1996–2001	1,510	1,170	1.3	1.0
2001–2006	3,250	2,120	1.9	1.5
2006–2013	4,740	2,390	1.7	1.3

Source: Statistics New Zealand

Figure 6.1



Source: Statistics New Zealand

Possible accuracy standards for subnational estimates (McNally & Bycroft, 2015) are split into two groups.

- For areas with population size of less than 100,000, 85 percent of total population estimates are within 5 percent relative error and all are within 10 percent.
- For areas with population size of 100,000 or more, all total population estimates are within 5 percent relative error.

Regional population estimates have met these possible accuracy standards over the last three intercensal periods (table 6.2).

Table 6.2

Percentage of absolute relative errors for population estimates within possible accuracy standards
16 regional council areas
1996–2013

Period	Population under 100,000		Population 100,000+	Most under-estimated RC area (RE %)	Most over-estimated RC area (RE %)
	% of RCs with ARE under:				
	5%	10%	5%		
1996–2001	100	100	100	Nelson (-3.1)	West Coast (4.3)
2001–2006	100	100	100	West Coast (-4.9)	Nelson (4.7)
2006–2013	100	100	100	Nelson (-3.8)	Marlborough (2.8)

Note: 10 regions have populations 100,000+ in 2001, 2006, and 2013.

Source: Statistics New Zealand

Bay of Plenty, Hawke’s Bay, and Taranaki regions were consistently under-estimated over the three intercensal periods. No regions were consistently over-estimated.

Territorial authority areas

Similar to the results for the national and regional estimates, the mean and median absolute relative errors for territorial authority areas (TAs) were higher for the 2001–06 period (table 6.3, figure 6.2). This higher error probably reflects the relatively high net migration during 2001–06 and its contribution to population change being under-estimated by the conventional PLT migration statistics, although several factors potentially contributed to the inaccuracy (see Sources of inaccuracy: Estimates).

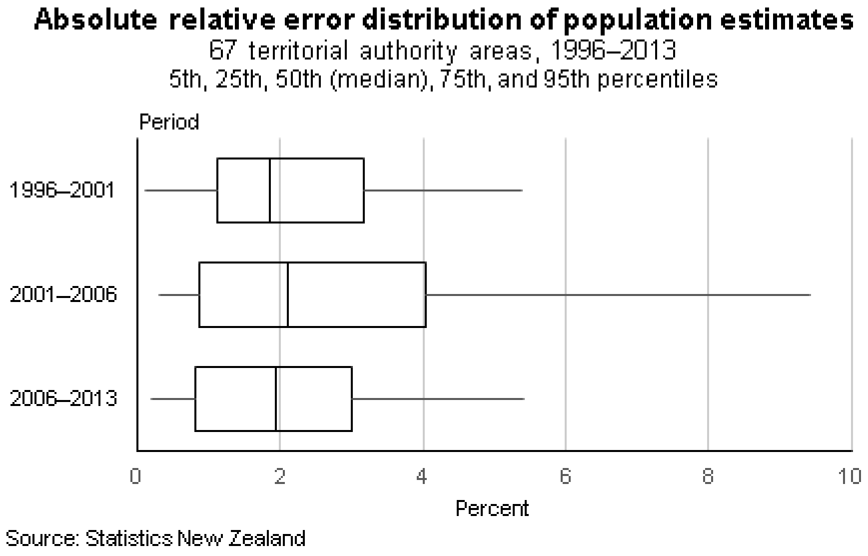
Table 6.3

Mean and median absolute errors and absolute relative errors of population estimates
67 territorial authority areas
1996–2013

Period	Mean absolute error	Median absolute error	Mean absolute relative error (%)	Median absolute relative error (%)
1996–2001	650	490	2.3	1.9
2001–2006	920	620	2.9	2.1
2006–2013	1,500	420	2.2	1.9

Source: Statistics New Zealand

Figure 6.2



Possible accuracy standards for subnational estimates (McNally & Bycroft, 2015) are split into two groups.

- For areas with population size of less than 100,000, 85 percent of total population estimates are within 5 percent relative error and all are within 10 percent.
- For areas with population size of 100,000 or more, all total population estimates are within 5 percent relative error.

Population estimates met these possible accuracy standards over the last intercensal period for all large TAs, but did not meet them for smaller TAs (table 6.4).

Table 6.4

Percentage of absolute relative errors for population estimates within possible accuracy standards
67 territorial authority areas
1996–2013

Period	Population under 100,000		Population 100,000+	Most under-estimated TA (RE %)	Most over-estimated TA (RE %)
	% of TAs with ARE under:				
	5%	10%	5%		
1996–2001	92	98	100	Waitomo (-5.0)	Mackenzie (12.3)
2001–2006	80	95	100	Central Otago (-10.8)	Chatham Islands (15.2)
2006–2013	92	100	100	Carterton (-7.9)	Ruapehu (4.8)

Note: Five TAs have populations 100,000+ in 2001; seven TAs have populations 100,000+ in 2006 and 2013. Shaded values are those not meeting the possible accuracy standards.

Source: Statistics New Zealand

Palmerston North, Chatham Islands, Queenstown-Lakes, and Dunedin TAs were consistently over-estimated over the three intercensal periods. In contrast, several TAs were consistently under-estimated: Matamata-Piako, Waipa, South Waikato, Tauranga, Hastings, Napier, New Plymouth, Stratford, South Taranaki, Wanganui, Tararua, Horowhenua, Carterton, South Wairarapa, Waimakariri, Ashburton, Timaru, Gore, and Invercargill.

Auckland local board areas

The pattern for Auckland local board areas (ALBAs) is generally one of increasing error over time (table 6.5, figure 6.3). In part this reflects the longer intercensal period of 2006–13 against the usual five-year period. It also reflects the methodological change whereby the ALBAs came into existence in 2010, part way through the 2006–13 period. Note: earlier estimates evaluated here were derived retrospectively from area unit population estimates.

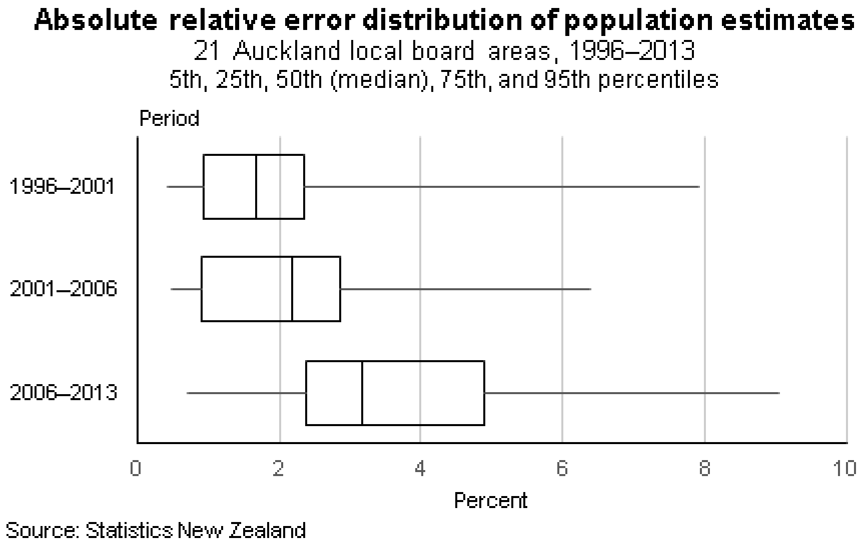
Table 6.5

Mean and median absolute errors and absolute relative errors of population estimates
21 Auckland local board areas
1996–2013

Period	Mean absolute error	Median absolute error	Mean absolute relative error (%)	Median absolute relative error (%)
1996–2001	1,060	870	3.1	1.7
2001–2006	1,720	1,220	2.9	2.2
2006–2013	2,730	2,380	3.9	3.2

Source: Statistics New Zealand

Figure 6.3



Possible accuracy standards for subnational estimates (McNally & Bycroft, 2015) are split into two groups.

- For areas with population size of less than 100,000, 85 percent of total population estimates are within 5 percent relative error and all are within 10 percent.
- For areas with population size of 100,000 or more, all total population estimates are within 5 percent relative error.

Population estimates met these possible accuracy standards over recent intercensal periods only for the largest ALBAs (table 6.6).

Table 6.6

Percentage of absolute relative errors for population estimates within possible accuracy standards
21 Auckland local board areas
1996–2013

Period	Population under 100,000		Population 100,000+	Most under-estimated ALBA (RE %)	Most over-estimated ALBA (RE %)
	% of ALBAs with ARE under:				
	5%	10%	5%		
1996–2001	86	95	…	Howick (-5.8)	Great Barrier (24.3)
2001–2006	84	95	100	Papakura (-6.4)	Waitemata (14.7)
2006–2013	74	100	100	Waitemata (-9.2)	Mangere-Otahuhu (9.0)

Note: No ALBAs had populations 100,000+ in 2001; two ALBAs had populations 100,000+ in 2006 and 2013. Shaded values are those not meeting the possible accuracy standards.

Symbol: … not applicable

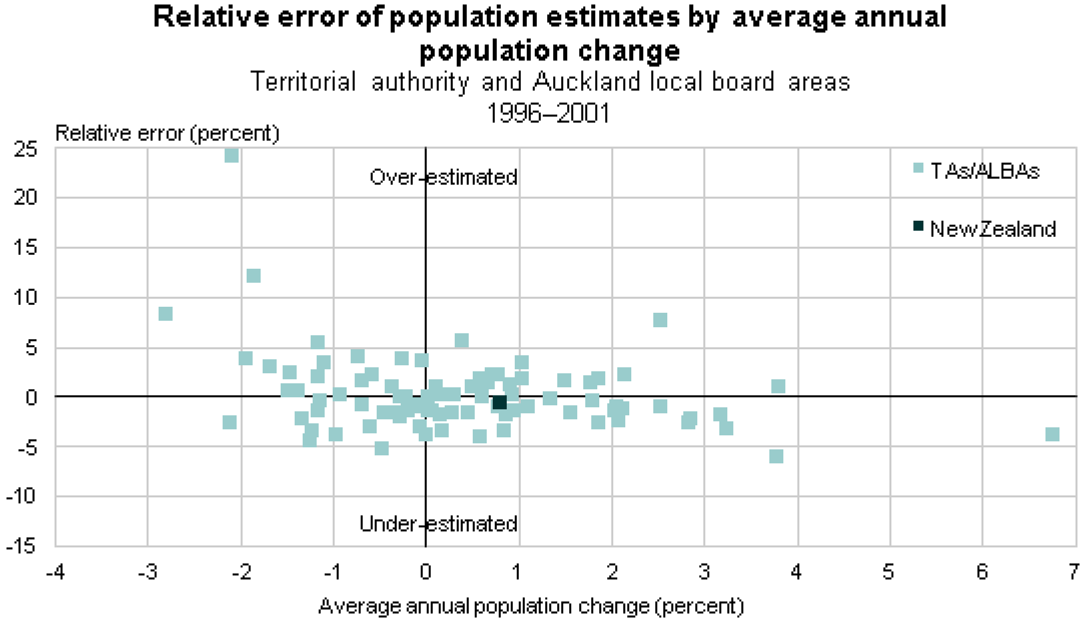
Source: Statistics New Zealand

Waitakere Ranges and Waiheke ALBAs were consistently over-estimated over the three intercensal periods. No ALBAs were consistently under-estimated.

Relative error by population change

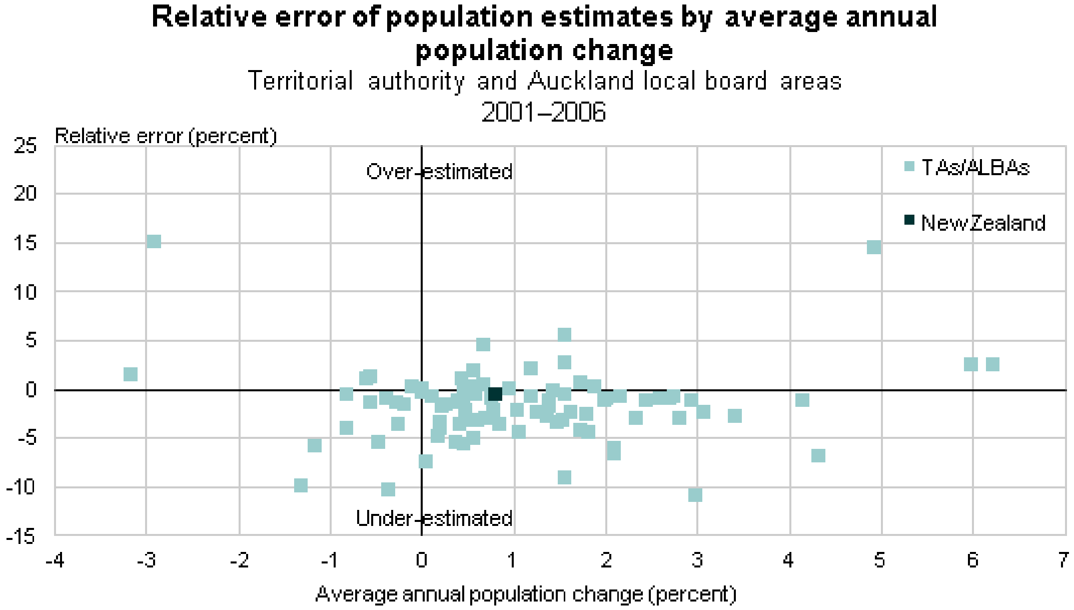
Comparing relative errors with population change may help determine the types of geographic areas that are more- or less-accurately estimated (figures 6.4–6.6). Generally, the slowest growing areas have the highest over-estimates, and the fastest growing areas have the highest under-estimates. However, the correlation is weak statistically, especially for the 2001-base estimates. Over the three intercensal periods, there is a diverse mix of population size and growth rate in the patterns of inaccuracy of population estimates.

Figure 6.4



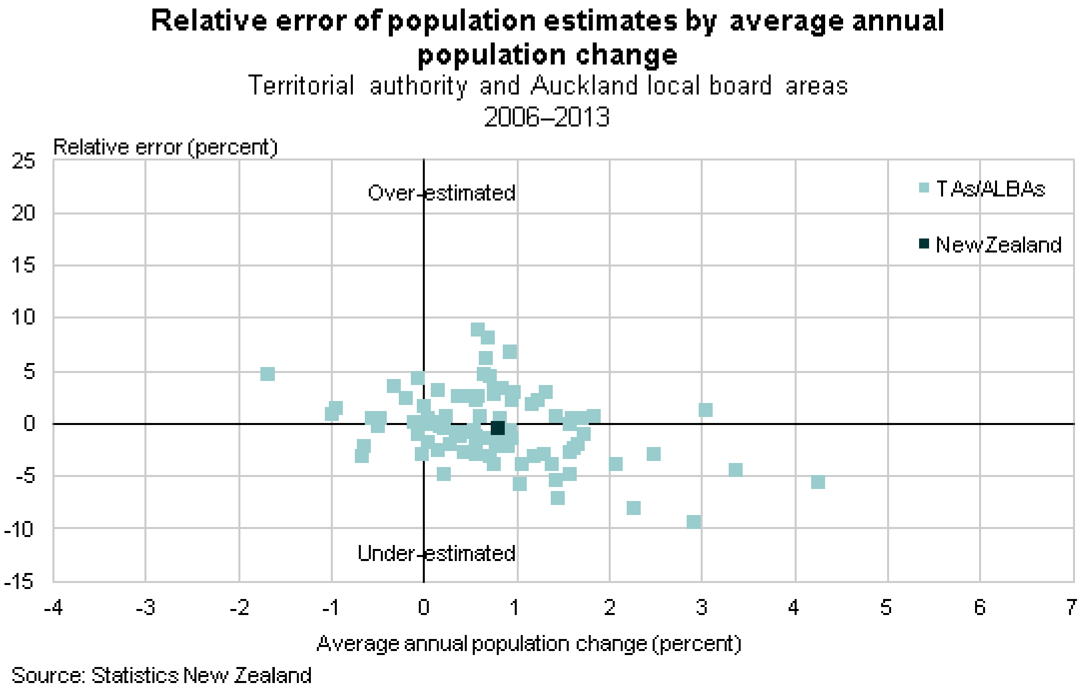
Source: Statistics New Zealand

Figure 6.5



Source: Statistics New Zealand

Figure 6.6



Area units

Patterns of accuracy

The patterns of accuracy observed for larger geographic areas were also observed for area units (AUs) (table 6.7, figure 6.7). Errors were higher for the 2001–06 period than the other two intercensal periods. Also, AUs with smaller populations generally had the greatest relative errors.

For analysis, it is useful to exclude AUs with particularly small populations (less than 100 people). This removes any with zero population, most of which consistently have zero population and are therefore estimated 'perfectly'. It also excludes AUs that fluctuate between zero and a non-zero population, which consequently have high (or uncalculatable) relative errors. This latter category has many AUs containing small islands, inlets, harbours, marinas, and small islands with small but mobile resident populations that live in mobile dwellings (ie boats).

The mean absolute relative error roughly halves as a result of excluding low-population AUs (<100 people), although the mean and median absolute errors are similar. This suggests it is important to consider both errors and relative errors when evaluating the accuracy of AU population estimates.

There was significant variability in the accuracy of population estimates for AUs. This partly reflects variations in population size and rates of population change. However, there is evidence of improving accuracy with lower average errors for the 2006–13 period, despite spanning a longer seven years. This may reflect the greater use of administrative data in AU population estimation, such as primary health organisation enrolments and Inland Revenue-based data.

Table 6.7

Mean and median absolute errors and absolute relative errors of population estimates
Area units
1996–2013

Period	Mean absolute error		Median absolute error		Mean ARE (%)		Median ARE (%)	
	All AUs	AUs 100+ popn.	All AUs	AUs 100+ popn.	All AUs(1)	AUs 100+ popn.	All AUs(1)	AUs 100+ popn.
1996–2001	110	120	70	70	4.3	6.8	4.6	4.4
2001–2006	130	130	70	80	16.6	7.1	5.0	4.6
2006–2013	110	110	60	70	14.7	7.1	3.8	3.6

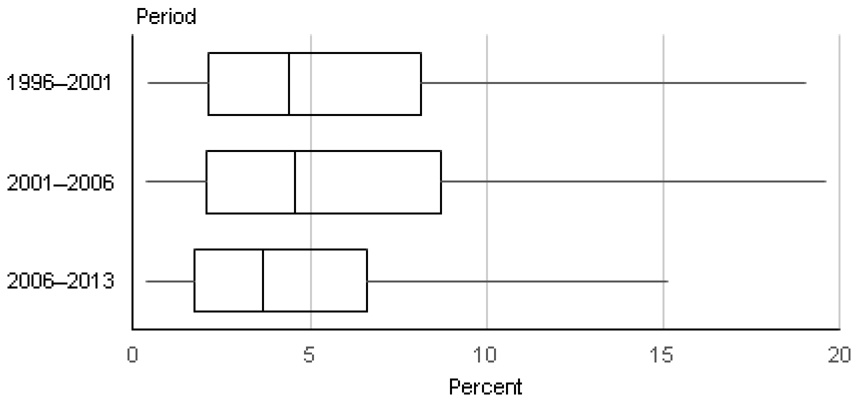
Note: There were 1,636 AUs with population 100+ in 2001, 1,684 AUs with population 100+ in 2006, and 1,739 AUs with 100+ population in 2013.

1. AUs with ERP of 0 at the end of the period are excluded because relative errors are incalculable.

Source: Statistics New Zealand

Figure 6.7

Absolute relative error distribution of population estimates
Area units of 100+ population, 1996–2013
5th, 25th, 50th (median), 75th, and 95th percentiles



Source: Statistics New Zealand

Possible accuracy standards for AUs are “80 percent of estimates for area units should be within 10 percent relative error, and all should be within 20 percent” (McNally & Bycroft, 2015). A pragmatic approach is to exclude AUs with less than 100 population. Of AUs with 100+ population, population estimates met the first possible accuracy standard, but did not meet the second, over all three intercensal periods (table 6.8).

Table 6.8

Percentage of absolute relative errors for population estimates within possible accuracy standards
Area units with 100+ population
1996–2013

Period	Number of AUs under-estimated	Number of AUs over-estimated	% of AUs with ARE under:	
			10%	20%
1996–2001 (1,630 AUs)	978	658	83	95
2001–2006 (1,677 AUs)	992	692	80	95
2006–2013 (1,738 AUs)	845	894	88	96

Note: Shaded values are those not meeting the possible accuracy standards.

Source: Statistics New Zealand

Outliers

It can also be revealing to analyse AUs with particularly large relative errors (eg AREs >50 percent after five years). The choice of this threshold is arbitrary and is simply a means of highlighting the largest AREs.

Excluding AUs under 100 population, the largest relative errors were a mix of over- and under-estimations, and tended to occur in AUs containing:

- central city areas (eg Whangarei Central; West Invercargill; Auckland Harbourside and Newmarket in Waitemata LBA; Porirua Central)
- marine areas with inconsistent numbers (over time) of people living on boats (eg Inlet-Waitemata Harbour in Auckland)
- large non-private dwellings susceptible to enumeration errors, respondent interpretation and identification of ‘usual residence’, and restructuring (eg Middlemore hospital in Otara-Papatoetoe LBA, Rangipo prison in Taupo district, Waiouru military camp in Ruapehu district)
- small populations – 20 of the 22 AUs with absolute relative errors >50 percent in any of the three intercensal periods had populations under 1,000.

Age groups

Regions

Similar to the national-level patterns, 15–19 year, 20–24, 25–29, and 85+ age groups were the least-accurate, followed by 35–39, 70–-79 and 80–84-year age groups (figure 6.9). Larger relative errors in the 15–19, 20–24, and 25–29-year age groups reflect their high gross and net migration flows. The larger relative errors in the older age groups (80–84 and 85+) partly reflects the smaller size of these populations.

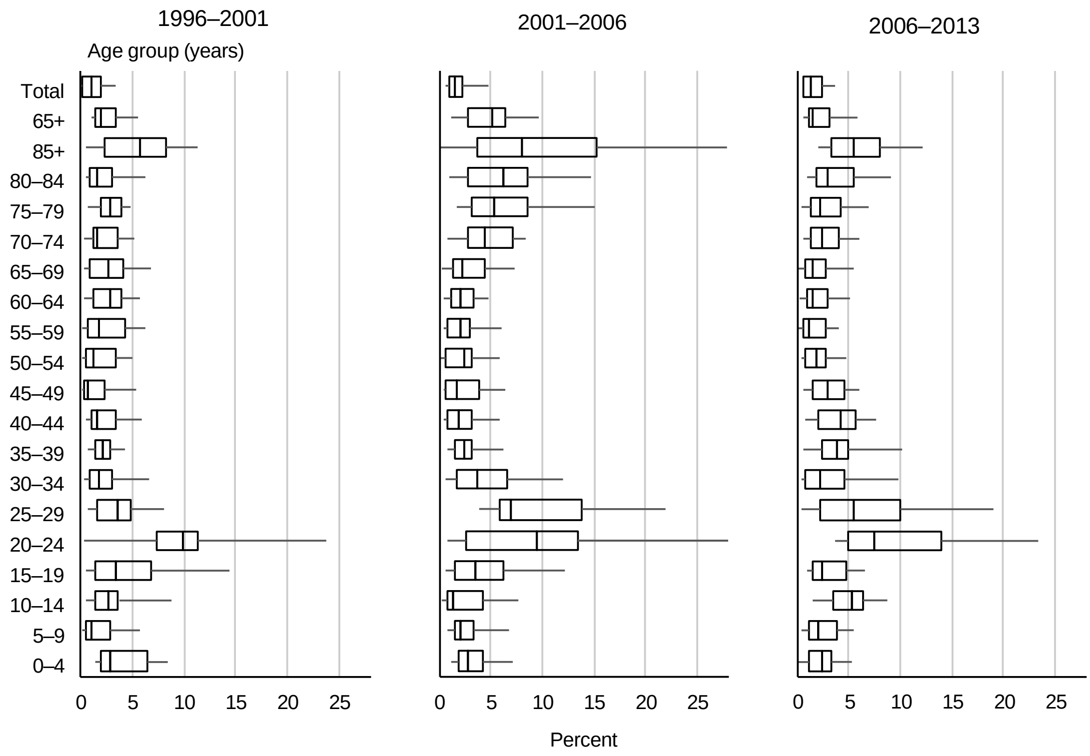
For example, the two Wellington region age groups 40–44 years and 85+ years both had absolute errors of 500 over the 2006–13 period. However, because the population was higher in the 40–44-year age group, the absolute relative error for that group was 1.2 percent. For the 85+ age group it was 6.0 percent.

Figure 6.8

Absolute relative error distribution of population estimates by five-year age group

16 regional council areas, 1996–2013

5th, 25th, 50th (median), 75th and 95th percentiles



Source: Statistics New Zealand

Possible accuracy standards for subnational areas by age groups (McNally & Bycroft, 2015) follow.

- For areas with population size of less than 100,000, 70 percent of estimates of the age groups are within 10 percent relative error, and all are within 25 percent.
- For areas with population size of 100,000 or more, all estimates for age groups are within 10 percent relative error.

Regional population estimates met these possible accuracy standards over recent intercensal periods for most, but not all, age groups (table 6.9).

Table 6.9

Percentage of absolute relative errors for population estimates within possible accuracy standards
16 regional council areas by age group
1996–2013

Age group (years)	1996–2001			2001–2006			2006–2013		
	Population under 100,000 (6 regions)		Population 100,000+ (10 regions)	Population under 100,000 (6 regions)		Population 100,000+ (10 regions)	Population under 100,000 (6 regions)		Population 100,000+ (10 regions)
	% RCs with ARE under:			% RCs with ARE under:			% RCs with ARE under:		
	10%	25%	10%	10%	25%	10%	10%	25%	10%
0–4	100	100	100	100	100	100	100	100	100
5–9	100	100	100	100	100	100	100	100	100
10–14	100	100	100	100	100	100	100	100	100
15–19	83	100	90	83	100	90	100	100	100
20–24	83	100	30	50	83	50	50	83	70
25–29	100	100	100	33	100	80	83	100	70
30–34	100	100	100	83	100	100	100	100	100
35–39	100	100	100	100	100	100	83	100	90
40–44	100	100	100	100	100	100	100	100	100
45–49	100	100	100	100	100	100	100	100	100
50–54	100	100	100	100	100	100	100	100	100
55–59	100	100	100	100	100	100	100	100	100
60–64	100	100	100	100	100	100	100	100	100
65–69	100	100	100	83	100	100	100	100	100
70–74	100	100	100	100	100	100	100	100	100
75–79	100	100	100	67	100	100	100	100	100
80–84	100	100	100	67	100	90	100	100	100
85+	67	100	100	33	67	70	67	100	100

Note: Shaded values are those not meeting the possible accuracy standards.

Source: Statistics New Zealand

Territorial authorities and Auckland local boards

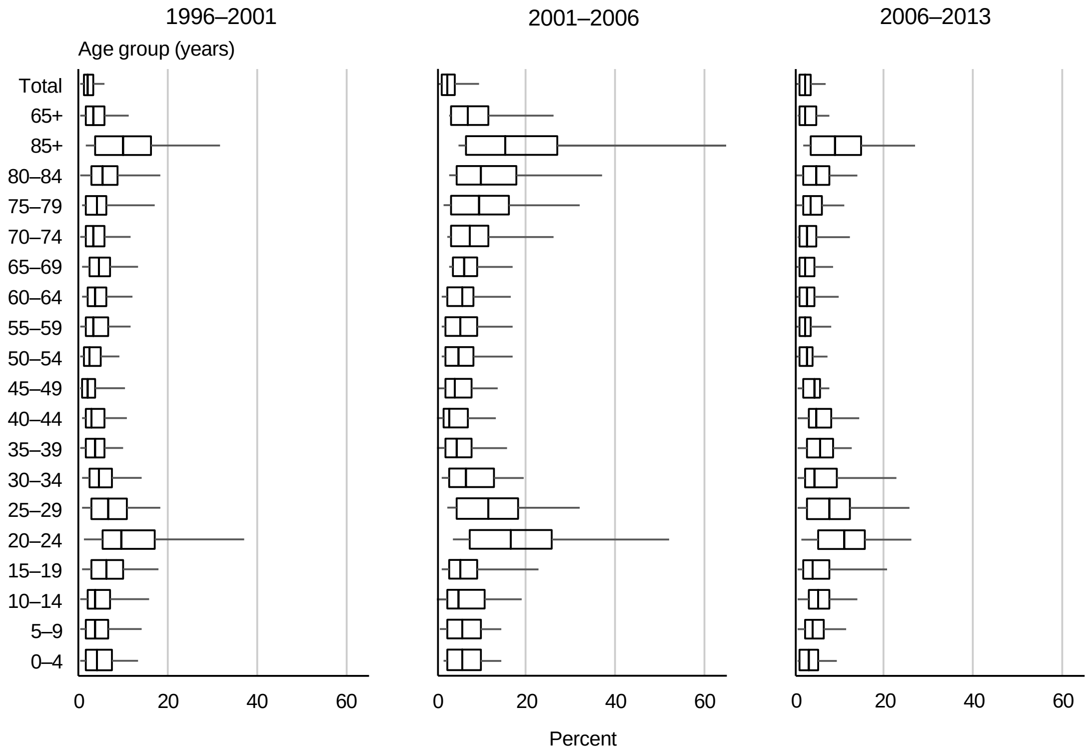
Similar to the regions, the 15–19 year, 20–24, 25–29, 80–84, and 85+ age groups were among the least accurate, along with the 5–9, 10–14, and 30–34-year age groups (figure 6.9). The inaccuracies partly reflect that some of these groups are the most susceptible to inaccuracies in net migration estimates – either external migration, internal migration, or both – while relatively small populations was a factor at the oldest ages.

Figure 6.9

Absolute relative error distribution of population estimates by five-year age group

66 territorial authority and 21 Auckland local board areas, 1996–2013

5th, 25th, 50th (median), 75th and 95th percentiles



Source: Statistics New Zealand

TA and ALBA population estimates met the possible accuracy standards over recent intercensal periods for only some age groups (table 6.10). Estimates for the 20–24 and 85+ age groups consistently missed the standards.

Table 6.10

Percentage of absolute relative errors for population estimates within possible accuracy standards

66 territorial authority and 21 Auckland local board areas by age group

1996–2013

Age group (years)	1996–2001			2001–2006			2006–2013		
	Population under 100,000 (4 areas)		Population 100,000+ (83 areas)	Population under 100,000 (8 areas)		Population 100,000+ (79 areas)	Population under 100,000 (8 areas)		Population 100,000+ (79 areas)
	% areas with ARE under:			% areas with ARE under:			% areas with ARE under:		
	10%	25%	10%	10%	25%	10%	10%	25%	10%
0–4	87	100	100	73	100	88	96	99	100
5–9	90	96	100	76	100	88	92	99	100
10–14	88	99	100	73	99	75	86	99	100
15–19	73	98	75	78	95	100	81	96	88
20–24	54	89	25	30	70	63	42	91	63
25–29	72	95	75	48	87	38	66	95	63
30–34	87	99	100	65	97	88	78	95	63
35–39	94	100	100	80	99	100	84	100	90
40–44	92	99	100	85	100	100	87	97	100
45–49	93	100	100	81	100	100	95	100	100
50–54	98	100	100	77	99	100	97	99	100
55–59	93	100	100	77	99	88	97	100	100
60–64	89	100	100	85	100	88	97	100	100
65–69	88	100	100	76	97	100	96	99	100
70–74	94	99	100	67	91	63	90	100	100
75–79	90	100	100	56	89	63	92	100	100
80–84	78	98	100	53	89	50	81	99	100
85+	51	86	75	38	66	38	56	94	75

Note: Shaded values are those not meeting the possible accuracy standards.

Source: Statistics New Zealand

7 Accuracy of New Zealand projections

This chapter reviews the accuracy of national (New Zealand) population projections, including projections of total population, age groups, and the components of population change.

Total population

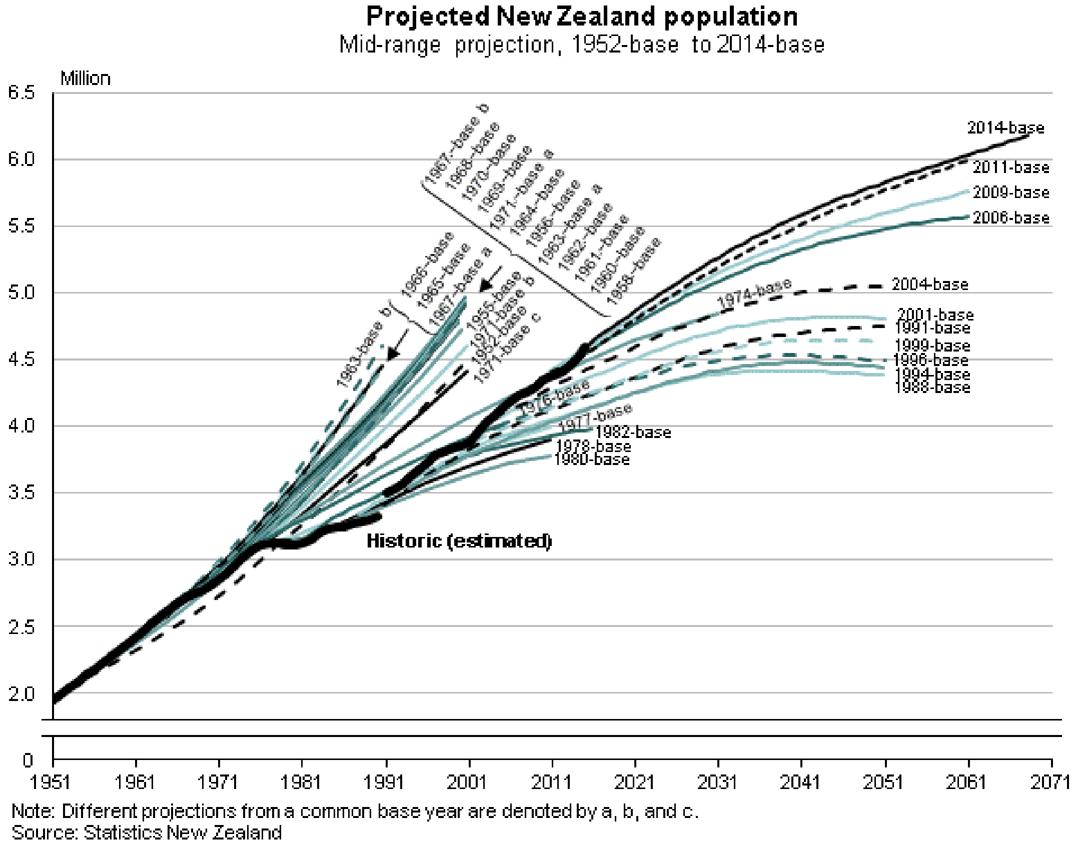
Historic projections from 1950s

Historic population projections produced before the 1990s are not available in any detail. Only summary results are available from printed publications. Nevertheless, mid-range projections of New Zealand's total population have varied considerably (see figure 7.1), reflecting several key points.

- Fertility assumptions affect population projections strongly. The prevailing fertility levels when the projections were produced is evident. For example, the period total fertility rate (TFR) exceeded 3.0 births per woman during the 1950s and 1960s. By the mid-1970s, the period TFR was under 2.5 births per woman. Since the late 1970s, it has generally been 1.9–2.2 births per woman.
- Mid-range projections since the mid-2000s have incorporated higher net migration assumptions, following evidence of a pronounced shift in average annual net migration levels that followed changes to immigration policy (eg Immigration Act 1986, 1987). This level shift also reflected increasing temporary international migration, which saw more people arriving on work, student, and working-holiday visas rather than on traditional residence visas.
- Newer projections incorporated higher life-expectancy assumptions. For the total population this is most evident in the long term, and among projections for older age groups. The most-recent projections have adopted a more sophisticated approach to modelling death rates (Woods & Dunstan, 2014).
- There are conceptual shifts in the population being projected. Most notably, projections since the late 1990s use the 'estimated resident population' (ERP) as a base. Earlier projections used census counts or the 'estimated de facto population' as a base. For example, the June 2013 ERP is 200,000 (or 5 percent) higher than the March 2013 'census usually resident population count'.
- Statistics NZ always publishes multiple projections, in keeping with the view that: projections are not predictions, the future is inherently uncertain, and multiple alternative projections help convey that uncertainty and give customers a choice for their specific purposes.

Figure 7.1

7.1. Projected New Zealand population, mid-range projection, 1952-base to 2014-base



Projections from 1990s

Between 1991 and 2011, Statistics NZ published eight sets of national population projections (table 7.1). For the mid-range projections:

- after 5 years, they ranged from a 1.8 percent under-projection to a 1.0 percent over-projection (based on 8 sets of projections)
- after 10 years, they ranged from a 3.8 percent under-projection to a 0.3 percent over-projection (based on 6 sets)
- after 15 years, they ranged from a 2.9 to 5.2 percent under-projection (based on 4 sets)
- after 20 years, they ranged from a 4.4 to 6.4 percent under-projection (based on 2 sets of projections).

Table 7.1

Error and relative error of mid-range population projections
New Zealand
1991–2013

Projection	Comparison year	Error (000)	Relative error (%)
1991-base published 1992	1996	-30	-0.8
	2001	13	0.3
	2006	-121	-2.9
	2011	-193	-4.4
1994-base published 1994	1996	-42	-1.1
	2001	-33	-0.9
	2006	-193	-4.6
	2011	-281	-6.4
1996-base published 1997	2001	38	1.0
	2006	-128	-3.1
	2011	-212	-4.8
1999-base published 2000	2001	-3	-0.1
	2006	-159	-3.8
	2011	-230	-5.2
2001-base published 2002	2006	-75	-1.8
	2011	-136	-3.1
2004-base published 2004	2006	-32	-0.8
	2011	-66	-1.5
2006-base published 2007	2011	9	0.2
2009-base published 2009	2011	42	1.0

Source: Statistics New Zealand

Generally, errors compounded as the period from the base (starting point) increased. For example, both absolute and absolute relative errors tended to be higher after 10 years than after 5 years, and after 15 years than after 10 years. This was not always the case, because under-projection and over-projection errors sometimes offset each other.

Components of population change

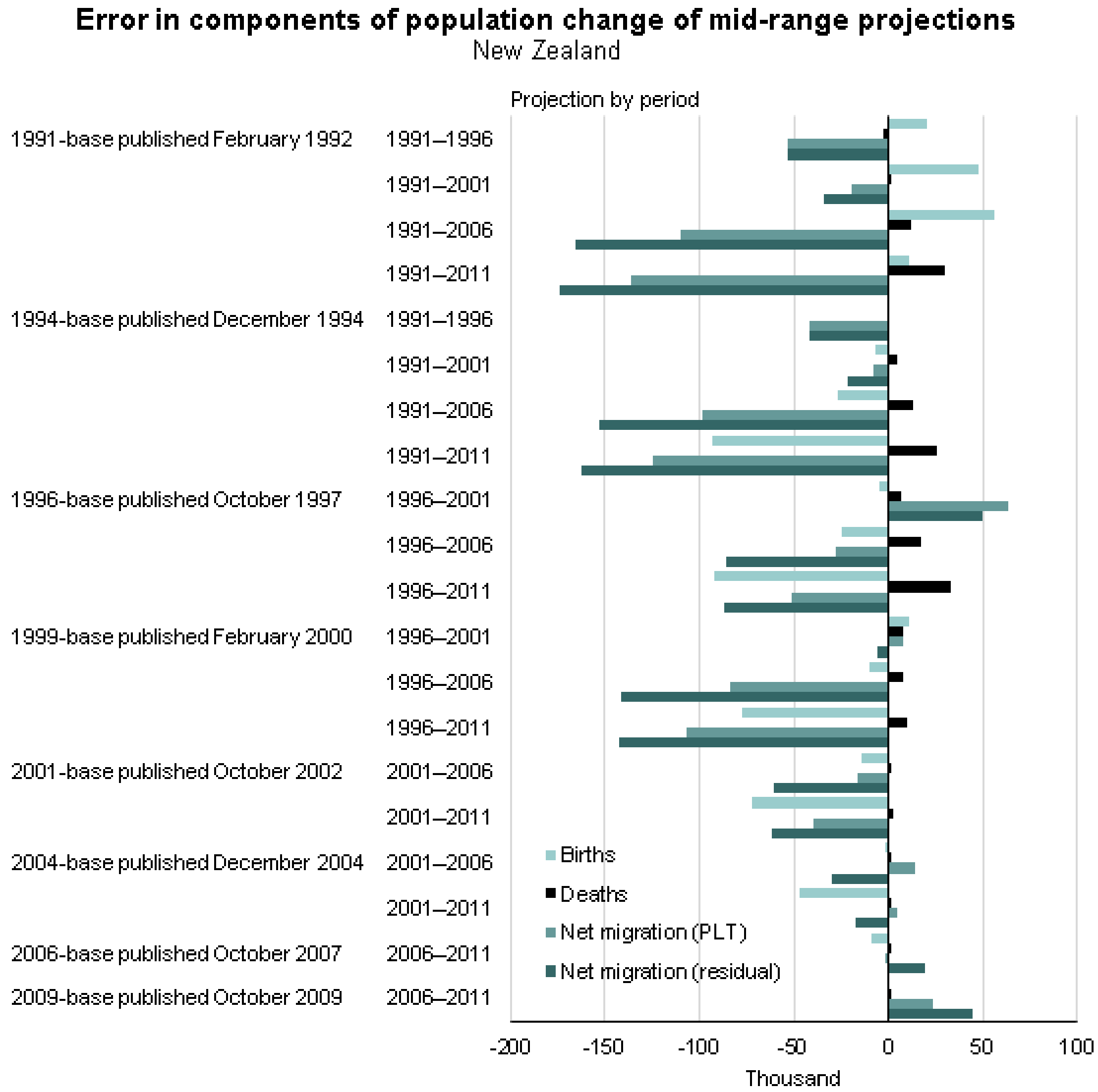
Deaths

Of the three components – births, deaths, and migration – death numbers from mortality/survivorship assumptions were projected most accurately over the 1991–2011 period (figure 7.2). This reflects that death rates and death numbers, although subject to annual fluctuations, have fluctuated within a relatively narrow band. For example, annual death registrations in the 20 years ended June 2011 were 26,800–29,300 (mean 27,800, standard deviation 800). Over this period there were no major wars or epidemics to invalidate the mortality assumptions.

Death rates at all ages generally trended downwards during1991–2011 and longer. This provides us with confidence in the mortality assumptions, at least in the short-run. In the long-run, their accuracy depends on whether future gains in longevity maintain the same rate of change as in recent decades.

An increasing over-projection of deaths in the 1991-base, 1994-base, and 1996-base projections indicates the under-projection of life expectancy in historic projections. Adopting an empirical model in 2012 for projecting age-specific death rates, from which life expectancy is subsequently derived, makes the mortality assumptions much more transparent and replicable than they used to be (Woods & Dunstan, 2014).

Figure 7.2



Source: Statistics New Zealand

Note:

1. Error: projected minus observed components.

2. All projections relate to June years except the 1991-base and 1994-base projections (March years).

3. All components relate to the resident population. Observed births and deaths are estimated occurrences in each period, based on birth and death registrations. Projected births and deaths are projected occurrences in each period.

4. Net migration (PLT): Observed net migration is 'permanent and long-term' migration.

5. Net migration (residual): The residual after subtracting estimated natural increase (births less deaths) from estimated population change during each period. This observed net migration estimate includes intercensal adjustments and therefore differs from 'Net migration (PLT)'.

6. For 1991–96, net migration (residual) equals net migration (PLT) – because the 1991 ERP is derived from the 1996 ERP by backdating population change components (including PLT net migration).

Births

National population projections tended to under-project birth numbers, with the exception of the 1991-base projections. This reflects lower long-run mid-range fertility assumptions (either 1.85 or 1.90 births per woman) than actually occurred (figure 7.2).

For births, the 1991-base national population projections over-projected birth numbers. By 2011, this over-projection had reduced to a difference of just 11,000 (0.9 percent). Fertility assumptions used in these projections were formulated when total fertility rates were high (TFR, 2.2 births per woman in 1990 and1991); the mid-range assumption drops to 1.95 births per woman in 2021.

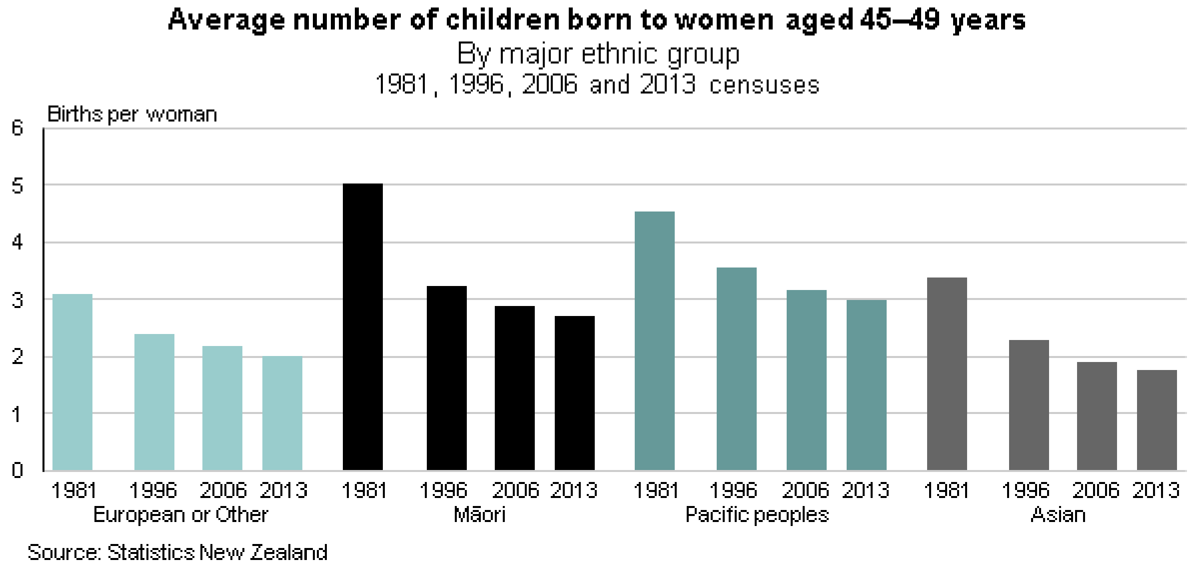
Annual birth numbers were more volatile than death numbers. In the 20 years ended June 2011, birth registrations were 54,000–64,100 a year (mean 58,700, standard deviation 2,900).

In an international context, TFRs in 2004–13 averaged 1.2–1.9 births per woman in 26 of the 34 OECD countries (OECD 2016). Another six countries, including New Zealand, averaged 2.0–2.1 births per woman over that period.

TFRs are a period measure and changes in TFRs over time can reflect changes in the timing of childbearing, rather than a real change in average family size. Completed or cohort fertility measures better indicate changes in actual family sizes. For example, women aged 45–49 years averaged 3.3, 2.5, 2.3, and 2.1 births during their lifetime at the 1981, 1996, 2006, and 2013 Censuses, respectively. Conversely, the proportion of women aged 45–49 years who were childless (ie they had borne no live children) was 9, 10, 13, and 16 percent at the same censuses, respectively. These trends are the same for all major ethnic populations (figures 7.3 and 7.4).

One interpretation of this is that a mid-range assumption of slightly lower fertility in future is still plausible, but the decline may be more gradual than previously assumed.

Figure 7.3



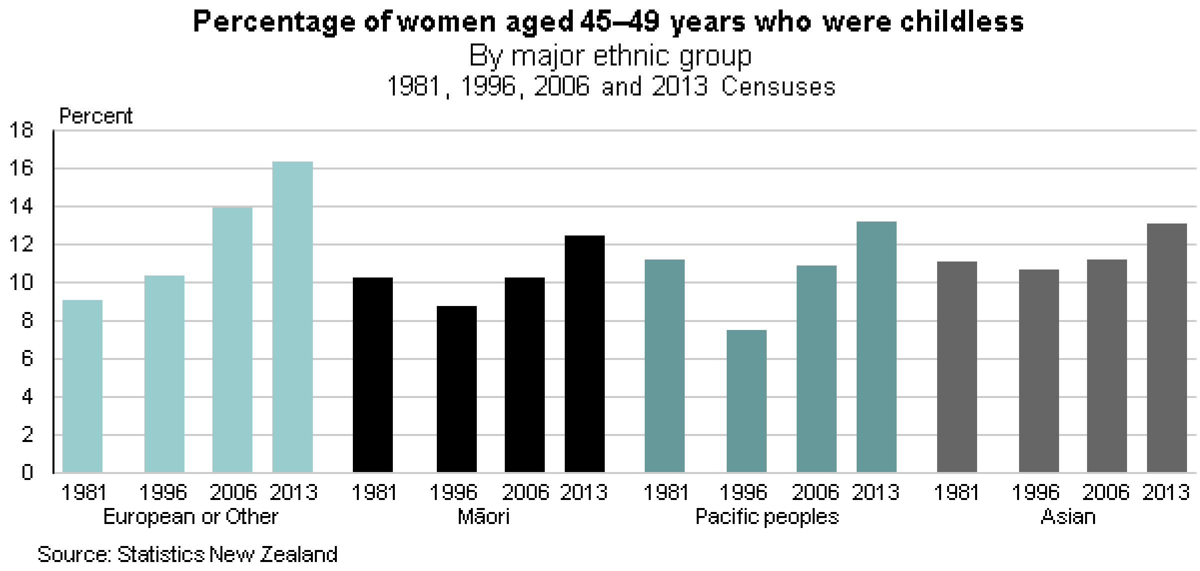
Note:

1. ‘European or Other’ includes women identifying with a European and/or an Other (including New Zealander) ethnicity.

2. Women who identify with more than one ethnicity are included in each ethnic group they identify with.

3. The Middle Eastern, Latin American, and African (MELAA) ethnic group is not included here.

Figure 7.4



Note: see Note under figure 7.3.

Migration

Assumptions for migration continue to be the most difficult to formulate. To a large extent, this reflects the volatility of New Zealand's external migration flows. In the four 5-year periods ending June 1996, 2001, 2006, and 2011, estimated net migration was 81,300; 700; 160,100; and 26,400, respectively (using a residual method). The residual method calculates net migration by subtracting estimated natural increase (births minus deaths) from the estimated population change during each period. For comparison, in the four 5-year periods ending June 1996, 2001, 2006, and 2011, 'permanent and long-term (PLT)' net migration was 81,300; -13,200; 116,600; and 47,700, respectively. In the 20 years ended June 2011, annual net PLT migration ranged from -11,400 in 1999 to 42,500 in 2003 (mean 11,600; standard deviation 13,700). Such swings are difficult to anticipate, given so many factors affect both arrivals and departures.

A significant shift in migration assumptions occurred between the 2001-base national population projections published in 2002 and those published in 2004. The long-run mid-range annual net migration assumption was raised from 5,000 to 10,000. While Statistics NZ has for many decades published national population projection series with a 10,000 annual migration level (and alternative higher levels of 15,000 and 20,000), the shift in the mid-range assumption to 10,000 recognised a different migration environment. This followed immigration policy changes in the late 1980s. For example, a long-run migration level of zero is now arguably unlikely to be sustained because government would use immigration policy to intervene and increase entry approvals, arrivals, and net migration.

In the 2011-base projections, Statistics NZ again lifted the mid-range assumption – to a long-run average of 12,000. However, these projections adopted a stochastic approach, which means the mid-range assumption does not relate to a specific simulation but is the statistical summary of 2,000 simulations of net migration. Those simulations have the same year-to-year variability as historical net migration. The assumptions imply a 50 percent chance that long-run net migration will be between 4,000 and 20,000 in any given year. They also imply that about 1 year in 6 will have more departures than arrivals, while 1 year in 15 will have net migration exceeding 30,000.

The most-recent mid-range assumptions appear to better reflect the current migration environment for immigration policy and more-temporary flows. Adopting a stochastic approach also better indicates the variability and uncertainty of New Zealand's migration balance.

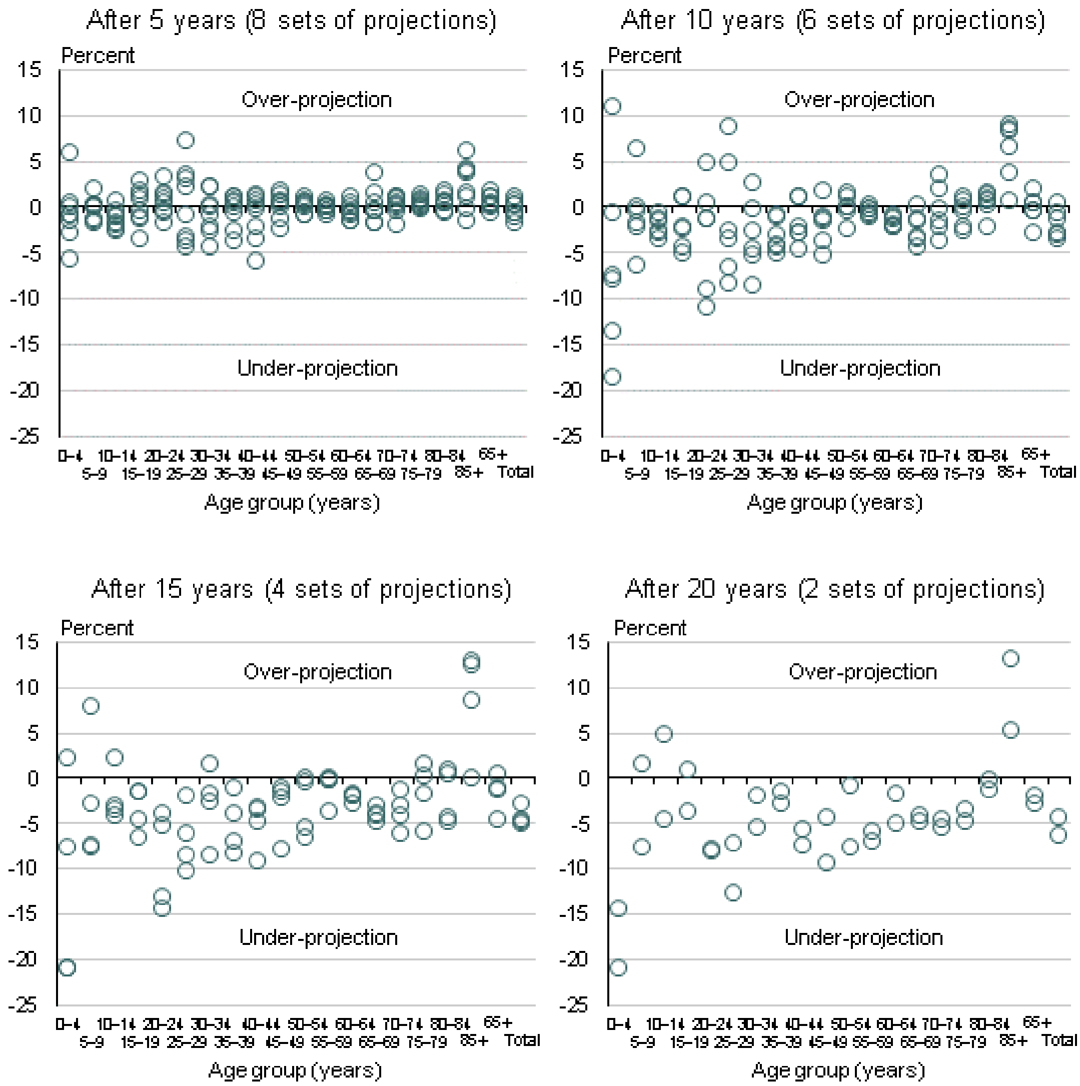
Age groups

For projections by age, the pattern of accuracy is more complex than for the total population, but these observations apply for 1991–2011 (figure 7.5).

- Projection accuracy generally decreased further from the base (starting point). That is, relative errors were higher after 20 years than after 15 years, after 15 years than after 10 years, and after 10 years than after 5 years.
- Every age group was both under-projected and over-projected at different times.
- The most-accurately projected age groups were 80–84, 55–59, 65+, 75–79, 50–54, and 60–64 years.
- The least-accurately projected age groups were 0–4, 25–29, 85+, and 20–24 years.
- Projection accuracy of the youngest age groups is particularly susceptible to fluctuations in births.
- Projection accuracy of the 20–29-year group is sensitive to fluctuations in migration.
- The broad 65+ age group was generally under-projected, but there was variation in this group. For example, the 85+ group was generally over-projected, while the 65–84-year group was generally under-projected. This largely reflects the assumption that mortality decreased at the same rate at all ages. However, for 1991–2011, larger decreases in death rates occurred under 85 years than over 85 years. The 2009-base projections were the first to incorporate different rates of change at different ages. This was developed further in the 2011-base projections (Statistics NZ, 2012b; Woods & Dunstan, 2014).

Figure 7.5

Relative error of mid-range projections for New Zealand
By age group
1991–2011



8 Accuracy of subnational projections

This chapter reviews the accuracy of subnational population projections – of the total population for regional council (RC) areas (regions), territorial authority (TA) areas (cities and districts), Auckland local board areas (ALBAs), and area units (suburbs). Projections by age group are then reviewed for larger subnational areas.

See **Accuracy of estimated and projected populations 1996–2013** (interactive Excel file) under 'Available files'. It compares estimated (and projected) population change with observed population change – for all regional council, territorial authority, and Auckland local board areas.

Regions

Patterns of accuracy

The patterns of accuracy observed for New Zealand, are also observed for RC areas (regions) (tables 8.1, 8.2; figure 8.1).

- Projections become less accurate as the time from the base increases.
- Projection updates during an intercensal period are more accurate than the initial set.

Table 8.1

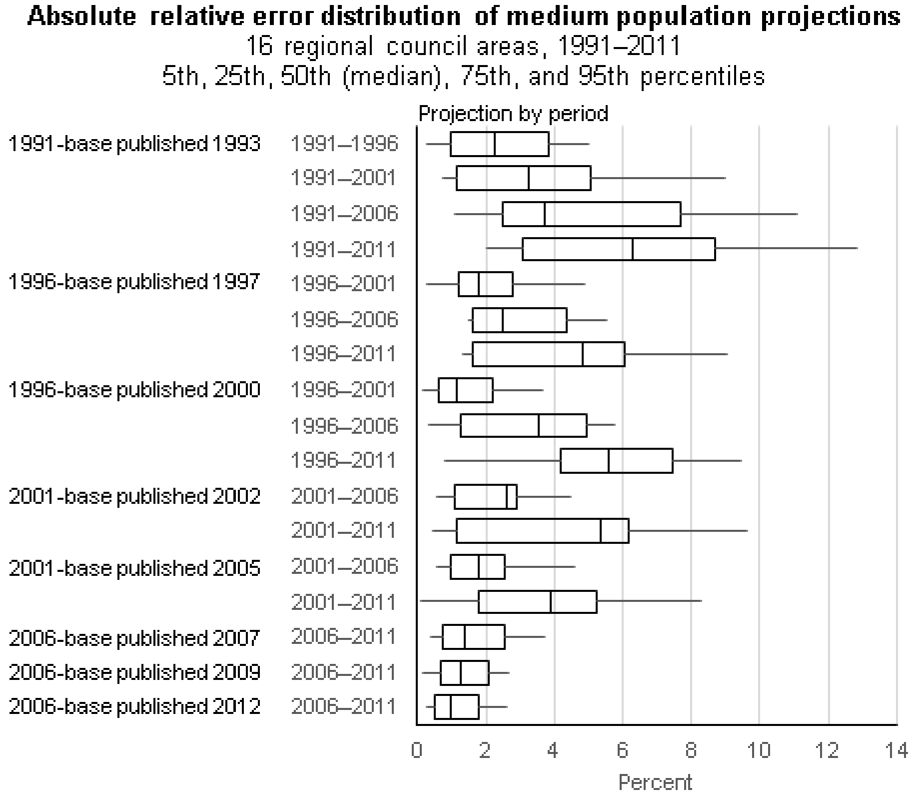
Mean and median absolute relative error of medium population projections
16 regional council areas
1991–2011

Projection	Comparison year	Mean absolute relative error (%)	Median absolute relative error (%)
1991-base published 1993	1996	2.4	2.3
	2001	3.6	3.2
	2006	5.1	3.7
	2011	6.6	6.3
1996-base published 1997	2001	2.2	1.8
	2006	3.0	2.5
	2011	4.5	4.8
1999-base published 2000	2001	1.5	1.1
	2006	3.1	3.5
	2011	5.5	5.6
2001-base published 2002	2006	2.3	2.6
	2011	4.6	5.3
2001-base published 2005	2006	2.0	1.8
	2011	3.7	3.9
2006-base published 2007	2011	1.7	1.4
2006-base published 2010	2011	1.4	1.2
2006-base published 2012	2011	1.2	1.0

Source: Statistics New Zealand

It is important to note the skewed distribution of regional populations. Of the 16 regions, Auckland is the largest and is roughly the size of the smallest 12 regions combined. As a result, the distribution of relative errors is skewed by the smaller regions.

Figure 8.1



Source: Statistics New Zealand

Table 8.2

Summary measures of relative error of medium population projections
16 regional council areas
1991–2011

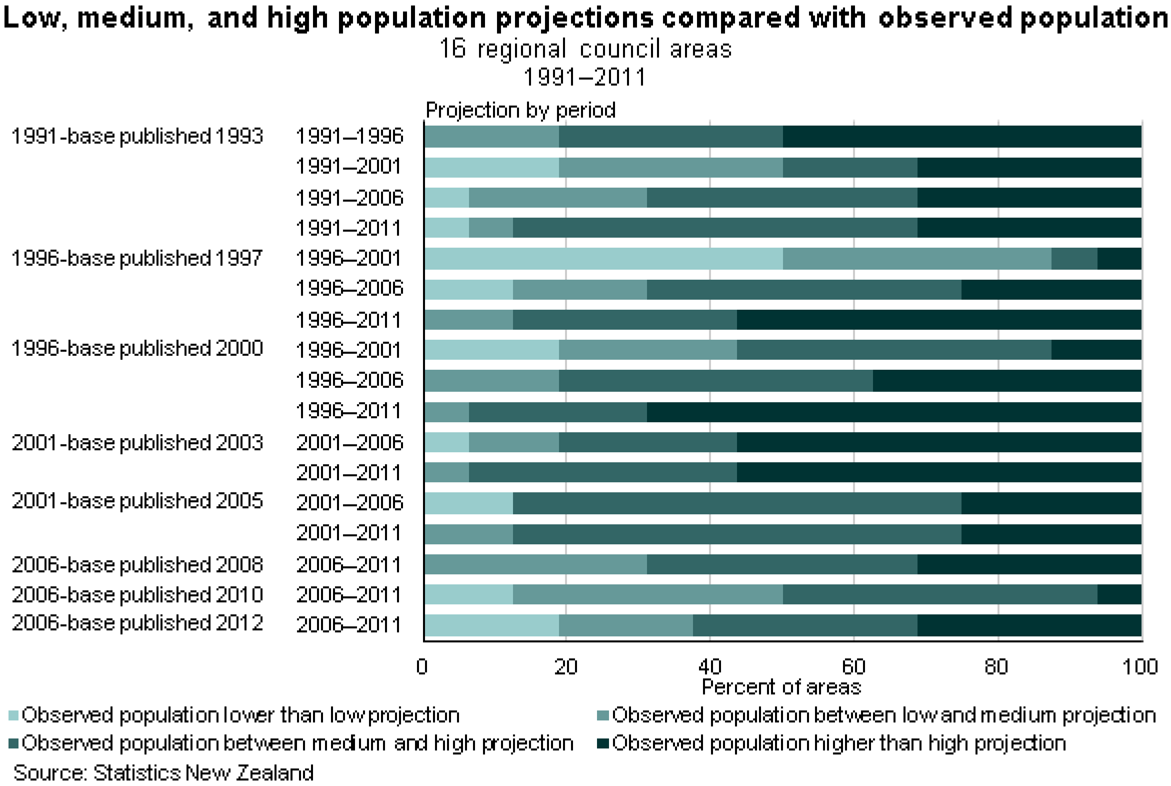
Projection	% of RC areas with ARE under: 5%	10%	Most under-projected RC area (RE %)	Most over-projected RC area (RE %)
5 years out from base population				
1991-base published 1993	94	100	Tasman (-5.5)	Manawatu-Wanganui (1.3)
1996-base published 1997	94	100	Tasman (-1.8)	West Coast (7.1)
1996-base published 2000	100	100	Tasman (-3.4)	West Coast (4.3)
2001-base published 2002	94	100	West Coast (-5.4)	Nelson (3.1)
2001-base published 2005	100	100	West Coast (-4.8)	Nelson (4.5)
2006-base published 2007	100	100	Nelson (-3.8)	Auckland (1.8)
2006-base published 2010	100	100	Nelson (-3.5)	Marlborough (2.4)
2006-base published 2012	100	100	Nelson (-2.7)	Marlborough (2.1)
10 years out from base population				
1991-base published 1993	75	100	Tasman (-9.5)	Manawatu-Wanganui (8.8)
1996-base published 1997	88	100	Wellington (-6.1)	Nelson (4.4)
1996-base published 2000	75	100	West Coast (-6.2)	Manawatu-Wanganui (1.4)
2001-base published 2002	44	94	West Coast (-11.1)	Bay of Plenty (1.1)
2001-base published 2005	63	100	West Coast (-9.3)	Tasman (5.1)
15 years out from base population				
1991-base published 1993	63	100	Tasman (-13.7)	Manawatu-Wanganui (10.2)
1996-base published 1997	50	100	Wellington (-9.8)	Manawatu-Wanganui (3.3)
1996-base published 2000	38	100	Southland (-9.8)	Manawatu-Wanganui (1.0)
20 years out from base population				
1991-base published 1993	44	75	Tasman (-15.8)	Manawatu-Wanganui (11.9)

Source: Statistics New Zealand

No region was consistently under- or over-projected during 1991–2011.

Figure 8.2 indicates the extent to which the collective ‘low-medium-high-growth’ projections encapsulate the observed population. This ranged from 81 percent of regions for 2006–11 (2006-base projections published 2010) to just 31 percent of regions for 1996–2011 (1996-base projections published 2000).

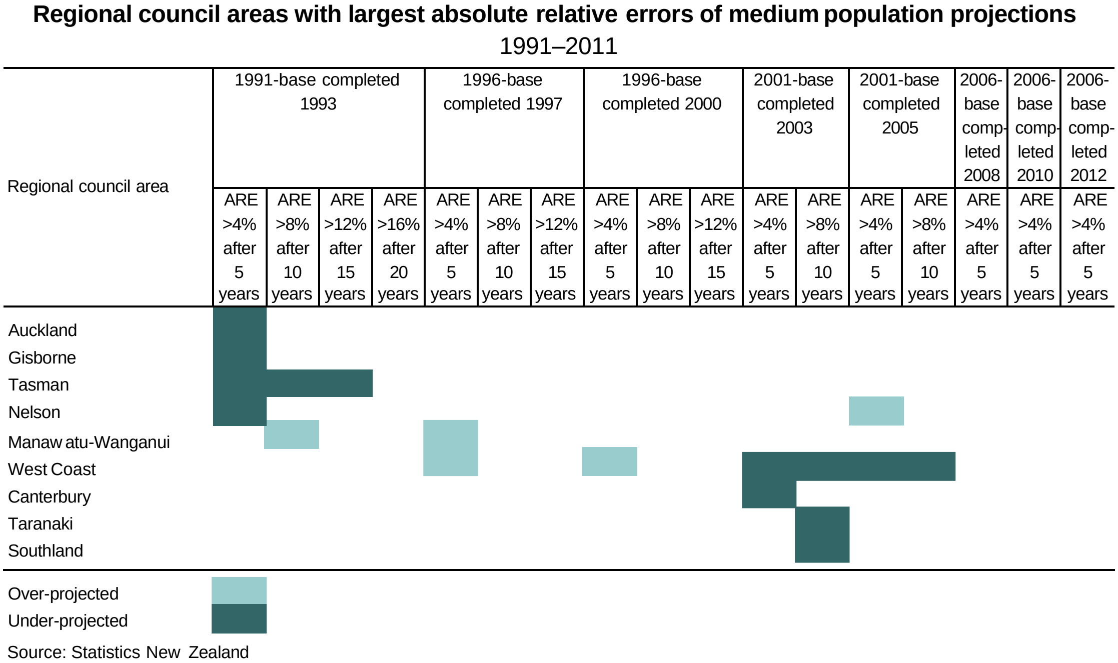
Figure 8.2



Outliers

It can be revealing to analyse regions with particularly large relative errors (eg AREs >4 percent after five years, >8 percent after 10 years, >12 percent after 15 years, >16 percent after 20 years) (figure 8.3). The choice of thresholds is arbitrary and is simply a way to highlight the largest AREs.

Figure 8.3



At the regional level, these large AREs do not persist. Generally, they were addressed in subsequent projections (ie by incorporating new population estimates, especially those based on new census counts). All 2006-base projections had regional AREs of less than 4 percent.

Nelson and West Coast, two of the smaller regions, had relatively large under/over-projections at different times (table 8.2, figure 8.3). This indicates their fluctuating net migration. For example, the observed net migration (external and internal migration combined) for Nelson was 2,800 between 1991 and 1996, but 600 between 2001 and 2006. Similarly, observed net migration for West Coast was -2,800 between 1996 and 2001, but 600 between 2001 and 2006 (Statistics NZ, 2015a). Such fluctuations are difficult to project.

Territorial authority areas

Patterns of accuracy

The patterns of accuracy observed for New Zealand and RC areas (regions) are the same for TA areas, except the range of errors is wider (tables 8.3, 8.4; figure 8.4).

- Projections become less accurate as the time from the base increases.
- Projection updates during an intercensal period are more accurate than the initial set.

Appendix 1 has additional figures.

Table 8.3

Mean and median absolute relative error of medium population projections
67 territorial authority areas, 1991–2011

Projection	Comparison year	Mean absolute relative error (%)	Median absolute relative error (%)
1991-base published 1993	1996	3.4	3.1
	2001	6.5	4.6
	2006	9.3	7.1
	2011	11.7	10.7
1996-base published 1997	2001	3.2	2.6
	2006	5.8	4.2
	2011	8.6	7.2
1996-base published 2000	2001	2.5	2.0
	2006	5.3	4.2
	2011	8.2	6.7
2001-base published 2002	2006	3.3	2.3
	2011	6.8	5.5
2001-base published 2005	2006	2.7	1.9
	2011	5.6	4.5
2006-base published 2007	2011	2.5	2.2
2006-base published 2010	2011	1.8	1.3
2006-base published 2012	2011	1.6	1.3

Source: Statistics New Zealand

Figure 8.4

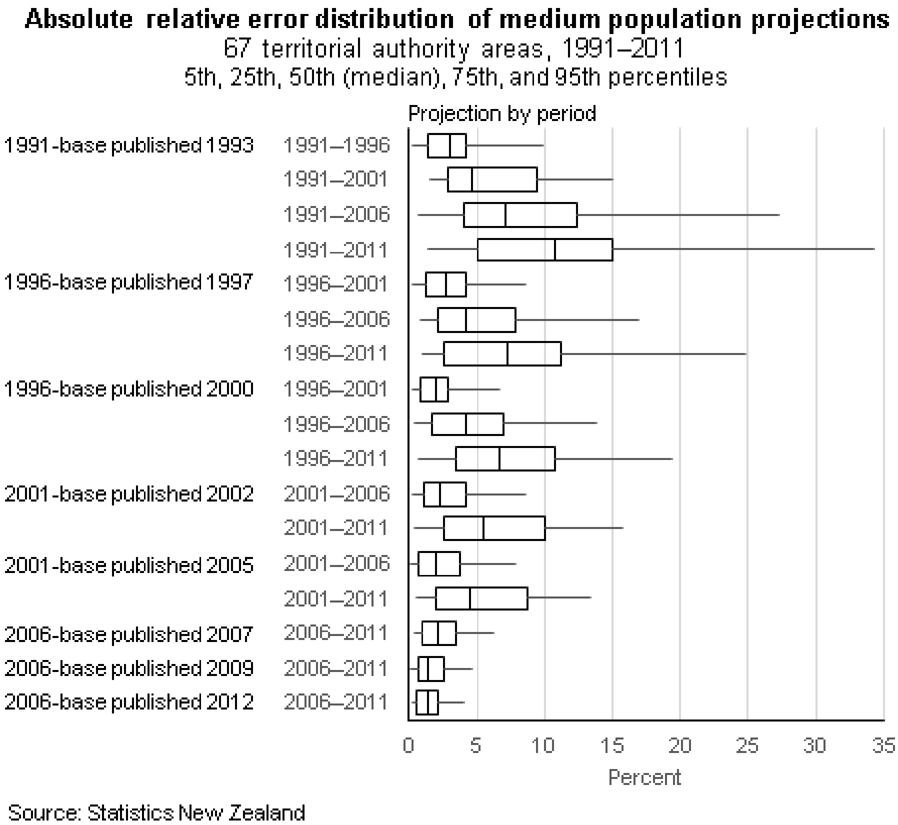

Absolute relative error distribution of medium population projections
67 territorial authority areas, 1991–2011
5th, 25th, 50th (median), 75th, and 95th percentiles
Projection by period
1991-base published 1993
1991–1996
1991–2001
1991–2006
1991–2011
1996-base published 1997
1996–2001
1996–2006
1996–2011
1996-base published 2000
1996–2001
1996–2006
1996–2011
2001-base published 2002
2001–2006
2001–2011
2001-base published 2005
2001–2006
2001–2011
2006-base published 2007
2006–2011
2006-base published 2009
2006–2011
2006-base published 2012
2006–2011
0
5
10
15
20
25
30
35
Percent
Source: Statistics New Zealand

Table 8.4

Summary measures of relative error of medium population projections
67 territorial authority areas, 1991–2011

Projection	% of TAs with ARE under:		Most under-projected TA (RE %)		Most over-projected TA (RE %)	
	5%	10%	All TAs	TAs 60,000+	All TAs	TAs 60,000+
5 years out from base population						
1991-base published 1993	85	96	Queenstown-Lakes (-15.6)	Auckland (-4.2)	Kawerau (9.9)	Rotorua (0.8)
1996-base published 1997	82	97	Tauranga (-4.7)	Tauranga (-4.7)	Ruapehu (13.3)	Palmerston North (4.1)
1996-base published 2000	87	99	Queenstown-Lakes (-5.1)	Hastings (-1.5)	Mackenzie (13.5)	Whangarei (1.7)
2001-base published 2002	84	96	Central Otago (-16.5)	Whangarei (-5.8)	Chatham Islands (16.8)	Tauranga (1.1)
2001-base published 2005	88	97	Central Otago (-10.9)	Whangarei (-4.8)	Chatham Islands (16.6)	Rotorua (0.4)
2006-base published 2007	90	100	Carterton (-8.9)	New Plymouth (-4.1)	Ruapehu (4.6)	Christchurch (4.2)
2006-base published 2010	97	100	Carterton (-7.4)	New Plymouth (-2.5)	Christchurch (4.6)	Christchurch (4.6)
2006-base published 2012	97	100	Carterton (-6.0)	New Plymouth (-2.1)	Westland (3.5)	Wellington (2.5)
10 years out from base population						
1991-base published 1993	54	82	Queenstown-Lakes (-20.0)	Tauranga (-9.5)	Kawerau (26.2)	Rotorua (6.0)
1996-base published 1997	58	82	Queenstown-Lakes (-18.3)	Tauranga (-10.1)	Chatham Islands (28.9)	Rotorua (3.5)
1996-base published 2000	58	88	Queenstown-Lakes (-23.4)	Wellington (-7.0)	Chatham Islands (28.0)	Rotorua (2.4)
2001-base published 2002	39	72	Central Otago (-25.0)	New Plymouth (-11.0)	Chatham Islands (17.9)	Rotorua (1.9)
2001-base published 2005	54	81	Selwyn (-17.9)	New Plymouth (-9.1)	Chatham Islands (17.7)	Rotorua (1.7)
15 years out from base population						
1991-base published 1993	34	60	Queenstown-Lakes (-34.1)	Tauranga (-14.1)	Chatham Islands (29.4)	Rotorua (7.8)
1996-base published 1997	42	70	Selwyn (-26.4)	Tauranga (-12.3)	Chatham Islands (34.5)	Rotorua (4.1)
1996-base published 2000	31	70	Queenstown-Lakes (-29.9)	New Plymouth (-11.5)	Chatham Islands (32.4)	Rotorua (3.5)
20 years out from base population						
1991-base published 1993	25	48	Selwyn (-40.4)	Tauranga (-15.1)	Opotiki (38.1)	Rotorua (13.1)

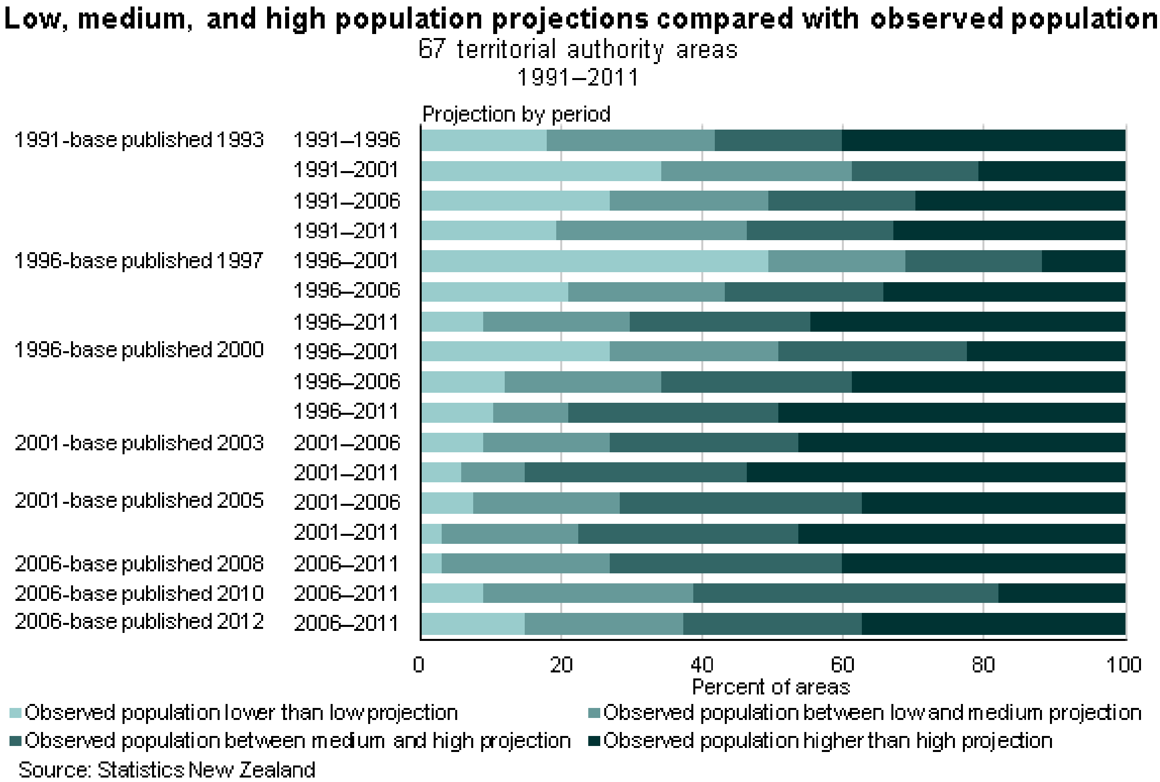
Note: 12 TAs have populations 60,000+ in 1996, 2001, and 2006; 14 TAs have populations 60,000+ in 2011. Source: Statistics New Zealand

Waikato, Waimakariri, Ashburton, and Timaru district TAs were consistently under-projected by the medium projections during 1991–2011, although often the RE was under 2 percent and the 'high' projections were an over-projection.

In contrast, Rotorua district was consistently over-projected by the medium projections over this period, although often the RE was under 1 percent and the 'low' projection was an under-projection.

Figure 8.5 indicates the extent to which the collective 'low-medium-high-growth projections' encapsulate the observed population. This ranged from 73 percent of TAs for 2006–11 (2006-base projections published 2010) to just 39 percent for 1996–2001 (1996-base projections published 1997).

Figure 8.5

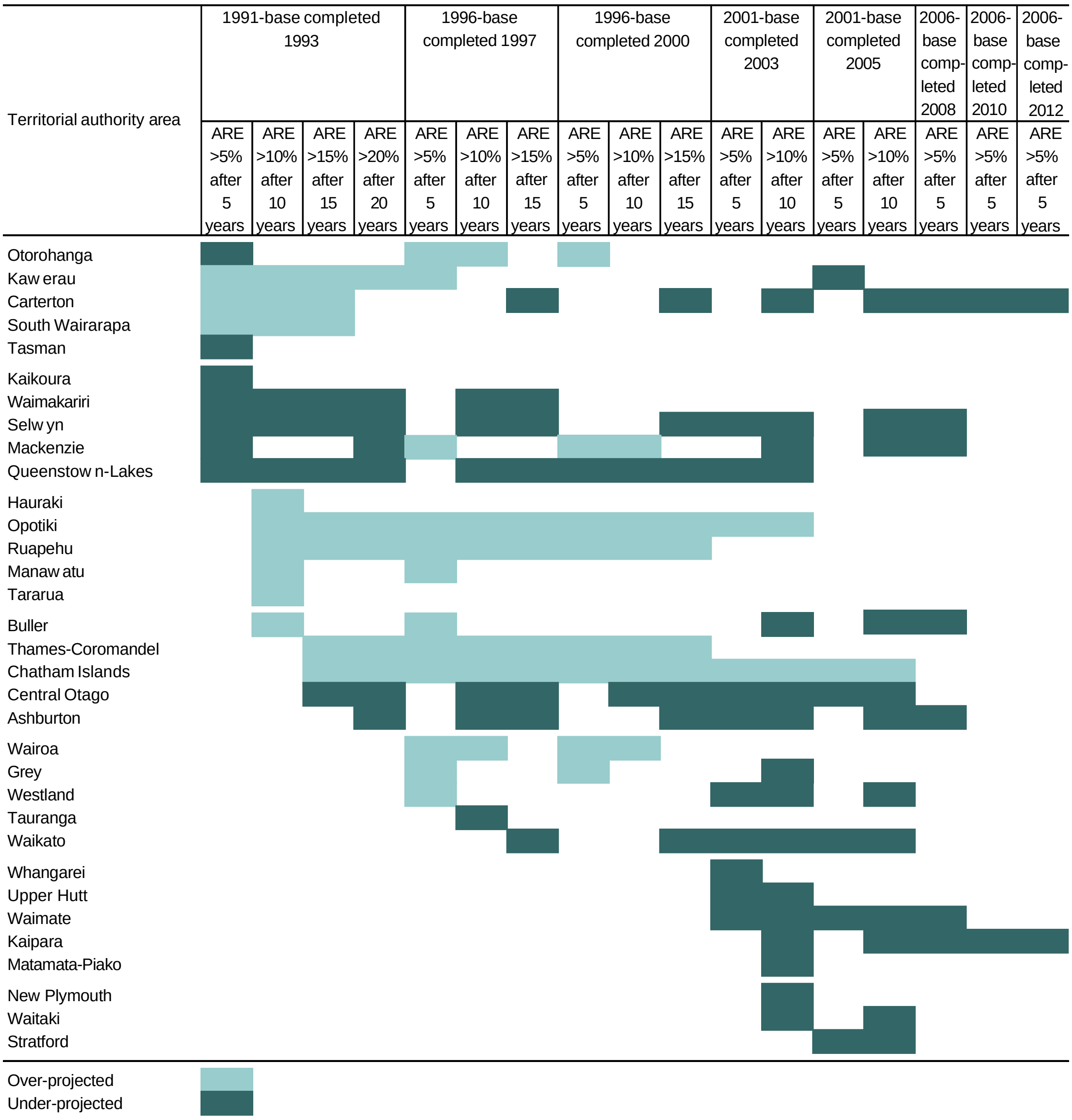


Outliers

It can be revealing to analyse TAs with particularly large relative errors (eg AREs >5 percent after five years, >10 percent after 10 years, >15 percent after 15 years, >20 percent after 20 years) (figure 8.6). The choice of thresholds is arbitrary and is simply a way to highlight the largest AREs.

Figure 8.6

Territorial authority areas with largest absolute relative errors of medium population projections
1991–2011



Source: Statistics New Zealand

At the TA level, these large AREs generally do not persist: they were addressed in subsequent projections (ie by incorporating new population estimates, especially those based on new census counts). The smaller TAs (eg Chatham Islands, Opotiki, Mackenzie) tend to have large AREs that persist.

Smaller TAs are also likely to experience significant fluctuations in net migration. Otorohanga, Kawerau, Carterton, Mackenzie, Buller, Grey, and Westland had relatively large under/over-projections at different times. This indicates their net migration fluctuations (Statistics NZ, 2015a). Such fluctuations are difficult to project.

Auckland local board areas

Patterns of accuracy

Among Auckland local board areas (ALBAs), the patterns of accuracy reflect those observed elsewhere (tables 8.5, 8.6; figure 8.7).

- Projections become less accurate as the time from the base increases.
- Projection updates during an intercensal period are more accurate than the initial set.

Appendix 1 has additional figures.

Table 8.5

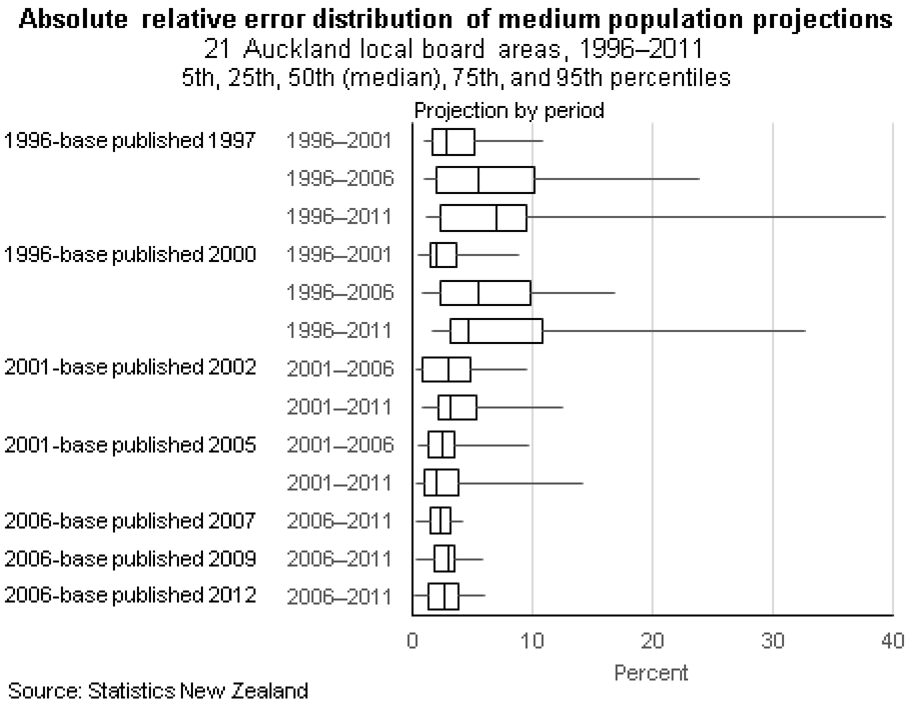
Mean and median absolute relative error of medium population projections
21 Auckland local board areas
1996–2011

Projection[1]	Comparison year	Mean absolute relative error (%)	Median absolute relative error (%)
1996-base completed 1997	2001	4.9	2.7
	2006	11.0	5.5
	2011	14.5	6.9
1996-base completed 2000	2001	3.6	1.9
	2006	9.2	5.4
	2011	11.5	4.6
2001-base completed 2003	2006	4.1	3.0
	2011	5.4	3.0
2001-base completed 2005	2006	3.7	2.5
	2011	4.2	1.9
2006-base completed 2008	2011	2.4	2.2
2006-base completed 2010	2011	2.9	3.0
2006-base completed 2012	2011	2.8	2.6

1. Derived from area unit population projections, except for those completed in 2012.

Source: Statistics New Zealand

Figure 8.7



Source: Statistics New Zealand

Table 8.6

Summary measures of relative error of medium population projections
21 Auckland local board areas
1996–2011

Projection	% of ALBAs with ARE under:		Most under-projected ALBA with 10,000+ population (RE %)	Most over-projected ALBA with 10,000+ population (RE %)
	5%	10%		
5 years out from base population				
1996-base completed 1997	71	90	Upper Harbour (-8.4)	Orakei (5.9)
1996-base completed 2000	81	95	Upper Harbour (-8.7)	Waitakere Ranges (5.2)
2001-base completed 2002	81	95	Papakura (-5.4)	Upper Harbour (9.5)
2001-base completed 2005	81	95	Papakura (-5.4)	Waitemata (9.7)
2006-base completed 2007	95	100	Upper Harbour (-3.5)	Otara-Papatoetoe (4.2)
2006-base completed 2010	86	100	Waitemata (-3.2)	Mangere-Otahuhu (5.7)
2006-base completed 2012	81	100	Waitemata (-7.3)	Mangere-Otahuhu (6.0)
10 years out from base population				
1996-base completed 1997	48	71	Upper Harbour (-20.9)	Waitakere Ranges (5.9)
1996-base completed 2000	48	76	Howick (-16.5) (1)	Waitakere Ranges (6.6) (1)
2001-base completed 2002	71	86	Papakura (-8.7)	Upper Harbour (10.2)
2001-base completed 2005	81	90	Papakura (-8.5)	Waitakere Ranges (5.1)
15 years out from base population				
1996-base completed 1997	43	76	Waitemata (-27.1)	Waitakere Ranges (9.5)
1996-base completed 2000	52	71	Waitemata (-21.3)	Waitakere Ranges (10.8)

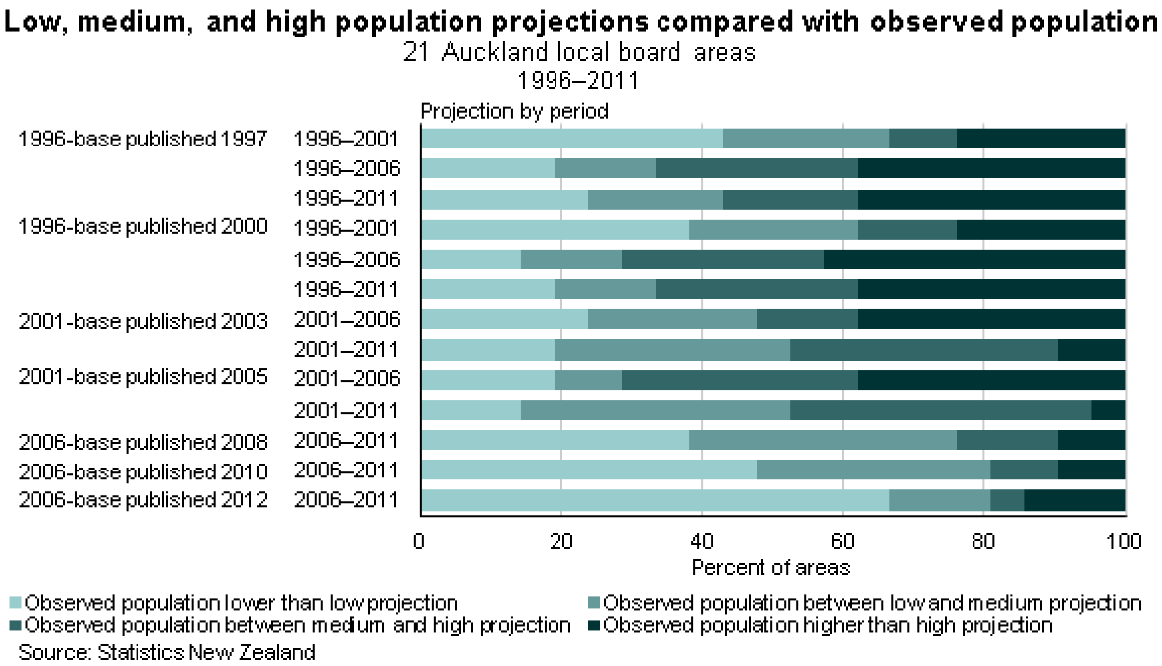
1.Updated to correct the most under-projected and over-projected ALBA and associated 'RE %' figures that were included in the 2016 published report: Upper Harbour (-16.5), and Waitakere Ranges (9.5).

Note: 19 ALBAs have populations 10,000+ in 2001, 2006, and 2011. Source: Statistics New Zealand

Waitakere Ranges, Waiheke, and Maungakiekie-Tamaki ALBAs were consistently over-projected by the medium projections during 1996–2011, although often the RE was under 1 percent and the 'low' projection was an under-projection. No ALBAs were consistently under-projected by the medium projections.

Figure 8.8 identifies the extent to which the collective 'low-medium-high-growth projections' encapsulate the observed population. This ranged from 81 percent of ALBAs for 2001–11 (2001-base projections published 2003) to just 19 percent of ALBAs for 2006–11 (2006-base projections published 2012). The results indicate the latter projections had too narrow a range between the low, medium, and high projections, largely reflecting migration assumptions were too narrow in range.

Figure 8.8



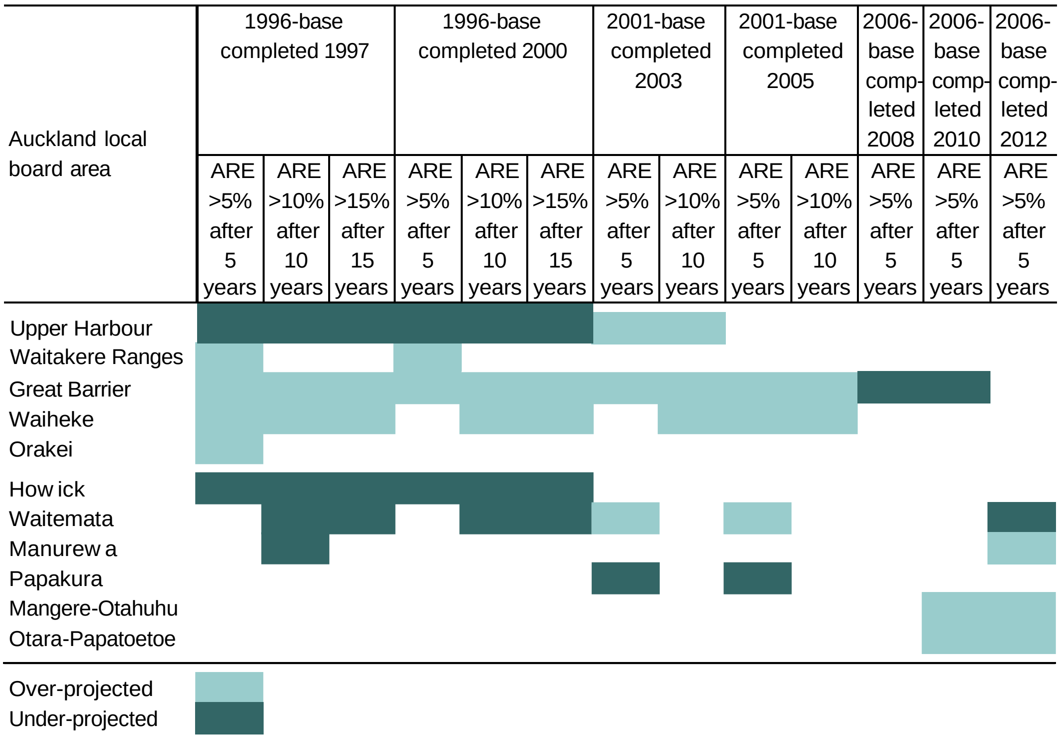
Outliers

It can be revealing to analyse ALBAs with particularly large relative errors (eg AREs >5 percent after five years, >10 percent after 10 years, >15 percent after 15 years) (figure 8.9). The choice of thresholds is arbitrary and is simply a way to highlight the largest AREs.

Figure 8.9

Auckland local board areas with largest absolute relative errors of medium population projections

1996–2011



Source: Statistics New Zealand

These large AREs generally do not persist, except for the smaller Great Barrier and Waiheke ALBAs. Generally, they were addressed in subsequent projections (ie by incorporating new population estimates, especially those based on new census counts).

There are some interesting reversals in the larger Upper Harbour and Waitemata ALBAs between over- and under-projection. Both areas had substantial net migration between 1996 and 2011, but projecting the precise level (and age-sex composition) is difficult. In such cases, it would seem prudent to reflect this uncertainty in wider alternative ‘low’ and ‘high’ net migration levels (in deterministic projections).

Area units

Patterns of accuracy

The patterns of accuracy observed for larger geographic areas, are also observed for area units (tables 8.7, 8.8, 8.9; figure 8.10)

- Projections become less accurate as the time from the base increases.
- Projection updates during an intercensal period are more accurate than the initial set.

For analysis, it is useful to exclude area units with particularly small populations (less than 100 people). This removes those with zero population, most of which consistently have zero population and are therefore projected 'perfectly'. It also excludes area units that fluctuate between zero and a non-zero population, which consequently have high (or uncalculatable) relative errors. In this latter category are many area units containing small islands, inlets, harbours, marinas, and islands with small but mobile resident populations that live in mobile dwellings (ie boats). Excluding these area units does not change the patterns of accuracy.

Appendix 2 has additional figures.

Table 8.7

Mean and median absolute relative error of medium population projections
Area units
1996–2011

Projection	Comparison year	Mean absolute error (%)		Median absolute error (%)	
		All AUs	AUs with 100+ population	All AUs	AUs with 100+ population
1996-base completed 1997 (N=1,175; 1,627)	2001	118	128	65	75
	2006	225	245	107	120
	2011	335	364	159	182
1996-base completed 2000 (N=1,175; 1,627)	2001	99	107	57	65
	2006	199	216	97	110
	2011	297	323	143	166
2001-base completed 2003 (N=1,860; 1,678)	2006	116	128	60	70
	2011	208	230	106	127
2001-base completed 2005 (N=1,860; 1,678)	2006	94	104	53	61
	2011	179	198	96	113
2006-base completed 2008 (N=1,927; 1,735)	2011	98	109	47	56
2006-base completed 2010 (N=1,927; 1,735)	2011	82	91	44	54
2006-base completed 2012(1) (N=1,927; 1,735)	2011	76	83	41	51

1. Projections are the same as those completed in 2010, except for update of the 167 AUs in Christchurch city, Waimakariri district, and Selwyn district – 162 of these had 100+ population.

Source: Statistics New Zealand

Table 8.8

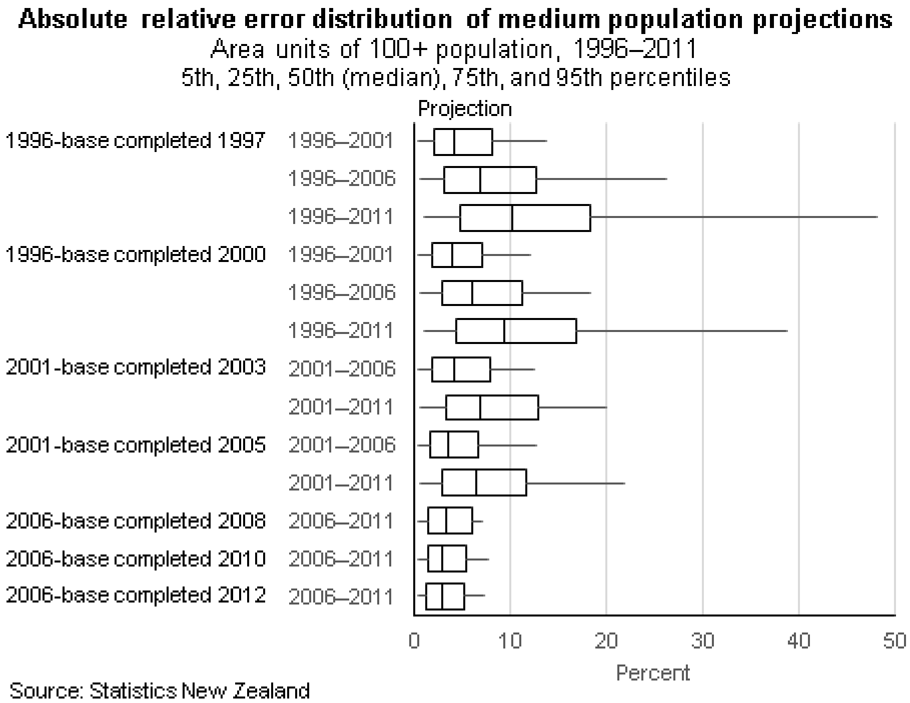
Mean and median absolute relative error of medium population projections
Area units of 100+ population
1996–2011

Projection	Comparison year	Mean absolute relative error (%)	Median absolute relative error (%)
1996-base published 1997 (N=1,627)	2001	6.5	4.1
	2006	10.5	6.8
	2011	14.8	10.1
1996-base published 2000 (N=1,627)	2001	5.7	3.8
	2006	9.6	5.9
	2011	13.6	9.2
2001-base published 2003 (N=1,678)	2006	6.2	4.1
	2011	10.4	6.9
2001-base published 2005 (N=1,678)	2006	5.2	3.5
	2011	9.0	6.3
2006-base published 2008 (N=1,735)	2011	5.2	3.2
2006-base published 2010 (N=1,735)	2011	4.3	2.9
2006-base published 2012(1) (N=1,735)	2011	4.0	2.8

1. Projections are the same as those completed in 2010, except for update of the 167 AUs in Christchurch city, Waimakariri district, and Selwyn district – 162 of these had 100+ population.

Source: Statistics New Zealand

Figure 8.10



Source: Statistics New Zealand

Table 8.9

Summary measures of relative error of medium population projections
Area units of 100+ population
1996–2011

Projection	% of AUs of 100+ population with ARE under:		
	5%	10%	20%
5 years from base population			
1996-base completed 1997 (N=1,627)	57	83	95
1996-base completed 2000 (N=1,627)	62	86	97
2001-base completed 2003 (N=1,678)	57	83	96
2001-base completed 2005 (N=1,678)	65	87	97
2006-base completed 2008 (N=1,735)	68	88	97
2006-base completed 2010 (N=1,735)	72	92	98
2006-base completed 2012(1) (N=1,735)	74	93	99
10 years from base population			
1996-base completed 1997 (N=1,627)	39	67	88
1996-base completed 2000 (N=1,627)	43	71	89
2001-base completed 2003 (N=1,678)	39	64	88
2001-base completed 2005 (N=1,678)	42	70	91
15 years from base population			
1996-base completed 1997 (N=1,627)	27	50	78
1996-base completed 2000 (N=1,627)	30	53	80

1. Projections are the same as those completed in 2010, except for update of the 167 AUs in Christchurch city, Waimakariri district, and Selwyn district – 162 of these had 100+ population.

Source: Statistics New Zealand

Outliers

It can be revealing to analyse area units with particularly large relative errors (eg AREs >50 percent after five years, >100 percent after 10 years, >150 percent after 15 years) (table 8.13). The choice of thresholds is arbitrary and is simply a way to highlight the largest AREs.

Excluding area units under 100 population, the largest REs were over- rather than under-projections, and tended to occur in area units containing:

- greenfield subdivisions that grew more slowly than projected (eg Silverdale North in Rodney ALBA; Long Bay and Waiwera in Hibiscus and Bays ALBA; Ormiston in Howich ALBA; Hingaia in Papakura ALBA; Peacocke, Rotokauri, and Te Rapa in Hamilton city; Churton Park (now Glenside North) and Grenada North in Wellington city)
- central city developments that grew fast, but not as fast as projected (eg Auckland Harbourside in Waitemata ALBA)
- small populations that declined rather than increased as projected (eg Kohukohu in Far North district, Mangere Station in Mangere-Otahuhu ALBA, Burbush in Hamilton city, Allen Road in Waipa district, Kawhia Community in Otorohanga district, Ohura in Ruapehu district)
- marine areas with inconsistent numbers of people living on boats (eg Inlet-Waitemata Harbour in Auckland) over time
- large non-private dwellings susceptible to enumeration errors, errors due to respondent concept and identification of ‘usual residence’, and restructuring (eg Middlemore hospital in Otara-Papatoetoe ALBA, Rangipo prison in Taupo district, Waiouru military camp in Ruapehu district).

The largest under-projections reflected very fast growing greenfield subdivisions that grew faster than projected from a small base (eg Sturges North in Waitakere Ranges/Henderson-Massey ALBAs, Rototuna in Hamilton city, Bethlehem East in Tauranga city, Nabhra (now Moonshine Valley) in Upper Hutt city).

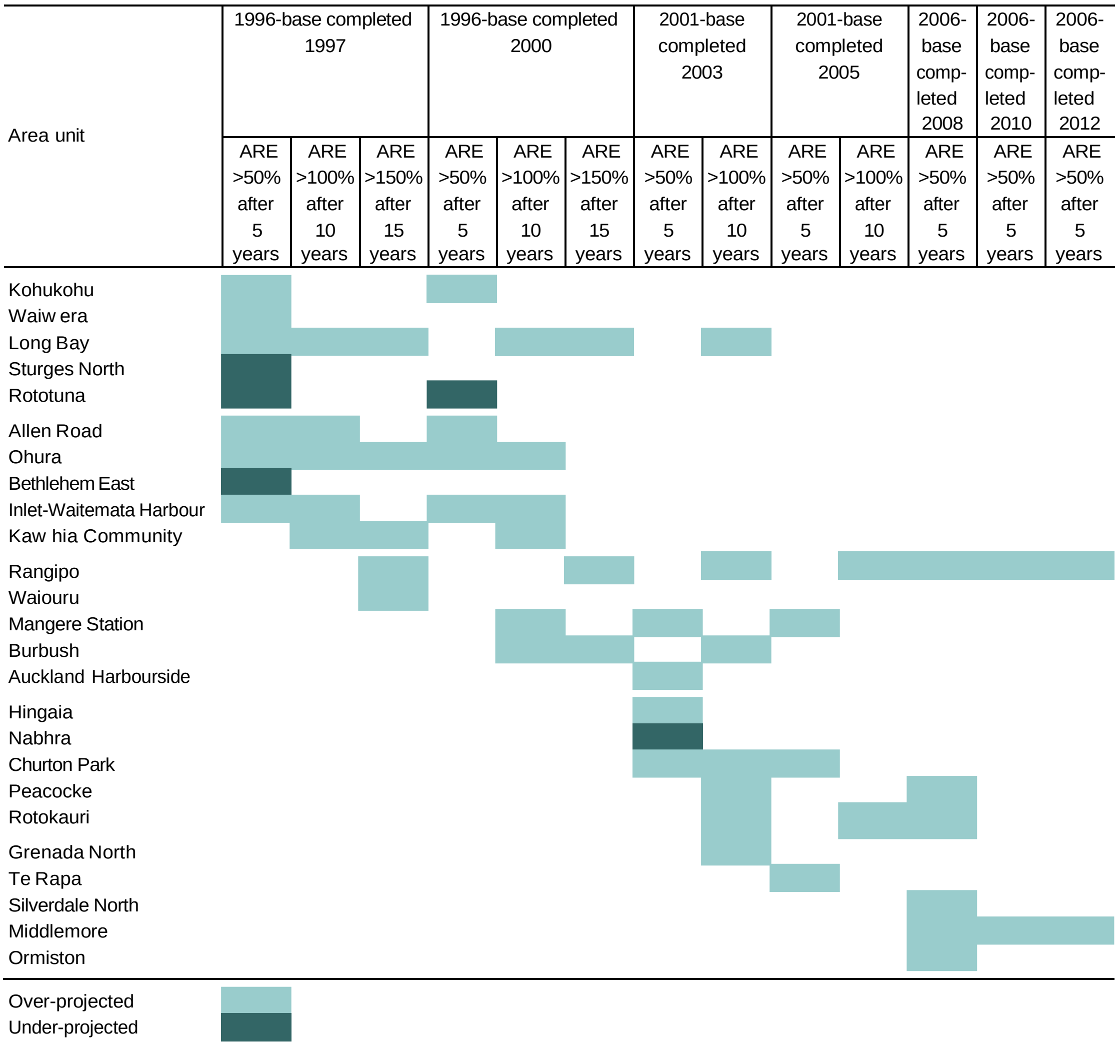
Generally, the large relative errors were addressed in subsequent projections (ie by incorporating new population estimates, especially those based on new census counts).

Figure 8.11

Area units with largest absolute relative errors of medium population projections

Area units of 100+ population

1996–2011



Source: Statistics New Zealand

Age groups

This section evaluates accuracy of the subnational population projections by five-year age groups over various projection horizons. The pattern of accuracy is more complex than national projections by age, but these observations apply for 1996–2011.

- Projection accuracy generally decreased as the period from the base (starting point) increased. That is, REs tended to be higher after 15 years than after 10 years, and after 10 years than after 5 years.
- As for the national projections, the most-accurately projected age groups were 80–84, 55–59, 65+, 75–79, 50–54, and 60–64 years.
- The least-accurately projected age groups were 0–4, 25–29, 85+, and 20–24 years; these also had greatest variation in accuracy across RCs/TAs/ALBAs.
- Projection accuracy for the youngest age groups is particularly susceptible to fluctuations in births. The 0–4 age group was under-projected in over half the RCs/TAs/ALBAs – across nearly all projections and periods analysed. This reflects the national projections' tendency to under-project births, as reflected in smaller

geographies because of the top-down approach applied to produce subnational projections.

- Projection accuracy for the 20–29-year age group is sensitive to migration. The relative inaccuracy mainly reflects their high migration rates. Migration can be both large in magnitude, and volatile, which can result in large errors over time.
- Subnational populations are subject to the added dynamic of internal migration (as well as external (international) migration), which results in wider error distributions for all ages than at the national level.
- The 85+ age group has significant variation in AREs, but due to being the smallest age-group population these are relatively small (numeric) errors.
- Age-group distribution is not uniform over New Zealand's sub-geographies, which can affect error distributions in difficult-to-project age groups.

Regions

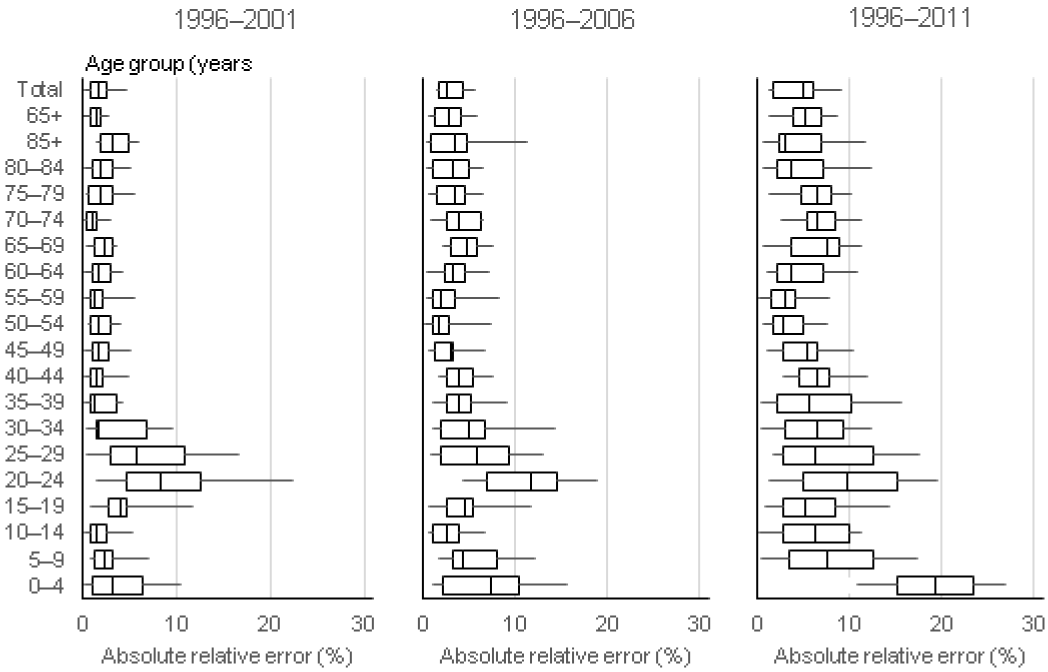
Along with these general comments, the following apply for regional population projections.

- In all regions, every age group was both under- and over-projected at different times, based on projections released between 2006 and 2013.
- Updated projections within an intercensal period were generally more accurate than initial projections for total populations, but for age group populations the results were mixed.
- Across all regions, the 0–4 age group was generally under-projected.
- Some of the largest errors and relative errors were in the mobile 20–29-year age group (figure 8.8). Most regions tended to be over-projected, but the largest (eg Auckland, Wellington) were under-projected.
- The broad 65+ age group was generally a more-accurately projected age group. But within this age group, 85+ was generally over-projected.

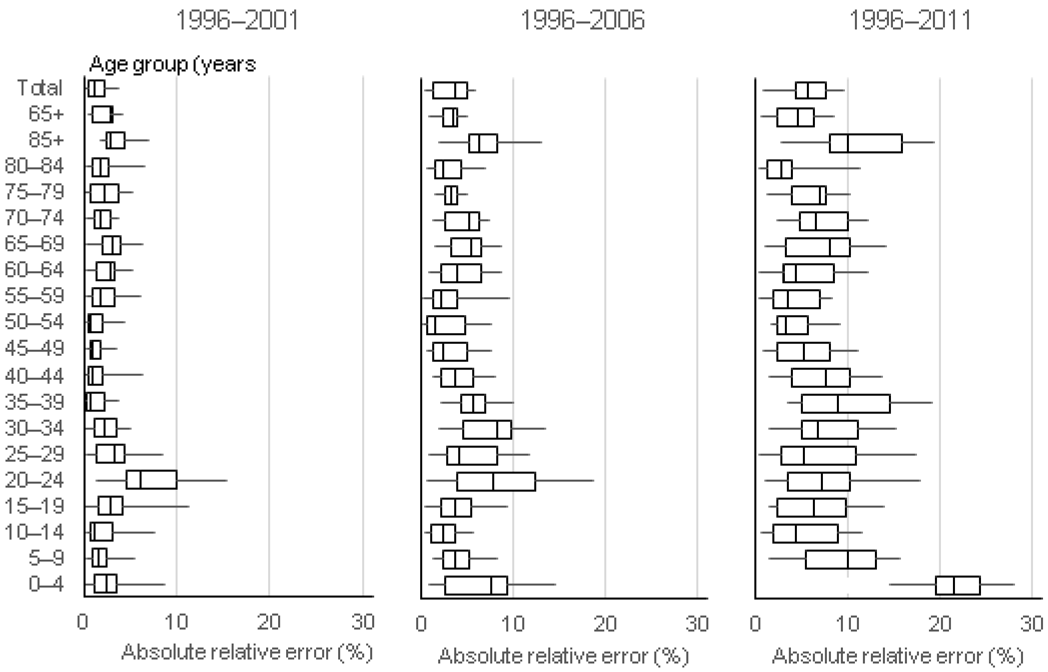
Figure 8.12

Absolute relative error distribution of medium population projections by age group
16 regional council areas, 1996–2011
5th, 25th, 50th (median), 75th, and 95th percentiles

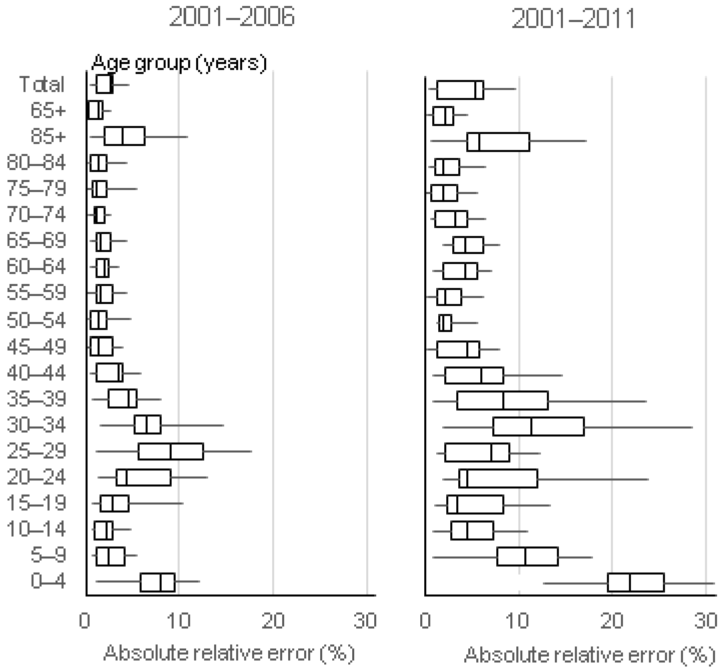
1996-base projections published 1997



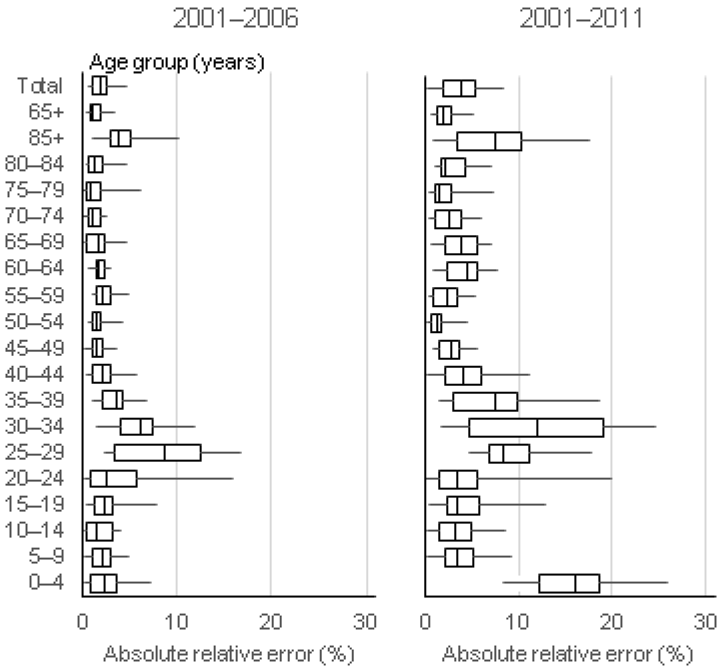
1996-base projections published 2000



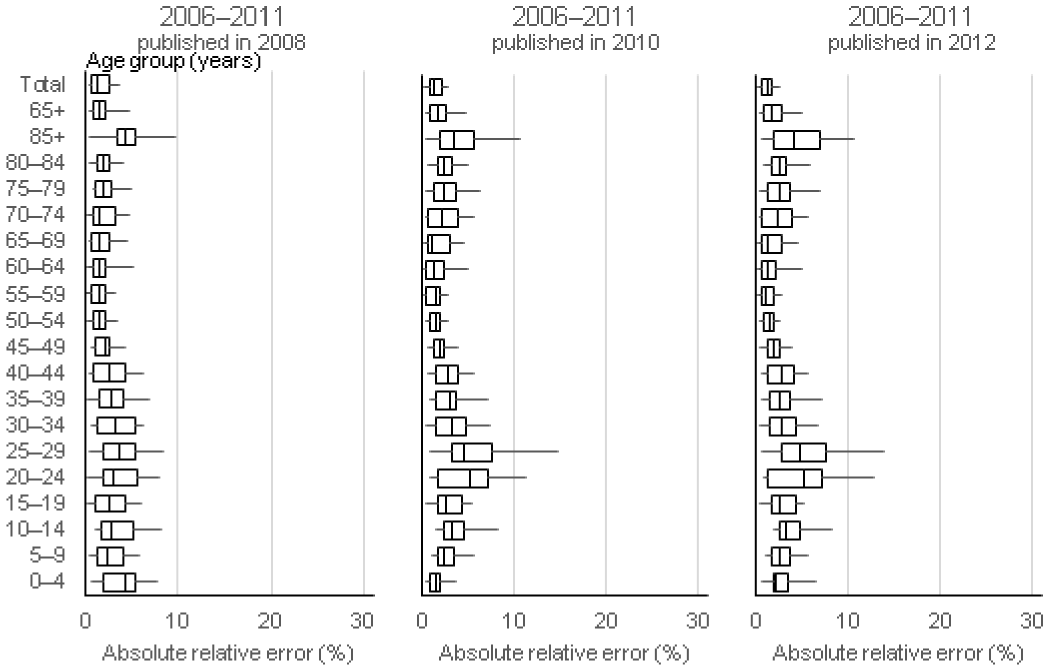
2001-base projections published 2003



2001-base projections published 2005



2006-base projections



Source: Statistics New Zealand

Territorial authority and Auckland local board areas

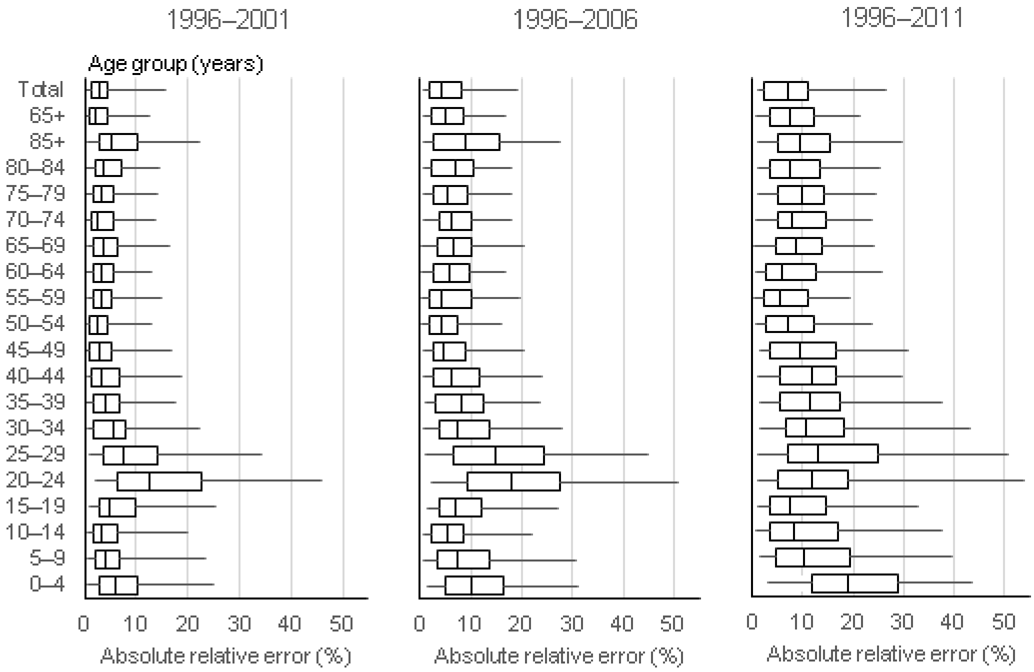
Along with the general comments for the national (Age groups) and regional levels (Regions), these comments apply for TA/ALBA projections.

- In all TAs and ALBAs, every age group was both under- and over-projected at different times, based on projections released between 2006 and 2013.
- The 20–29-year age group was over-projected in more than half the TAs and ALBAs, for most projections and comparison points, despite tending to be under-projected at the national level. This reflects smaller districts generally being over-projected, and larger cities generally being under-projected.
- AREs for all age groups were generally larger for TAs and ALBAs than regions, reflecting the former two having smaller average population sizes.
- The broad 65+ age group was generally a more-accurately projected age group. But within this group, 85+ was generally over-projected and 65–84 years was slightly under-projected in most TAs. This largely reflects the assumption that death rates decreased at the same rate at all ages; however, the decrease in recent decades was faster under 80 years than at 80+ years.
- The wide variation in projection accuracy for the 85+ age group also reflects its relatively small population. Small absolute errors can amount to large AREs.

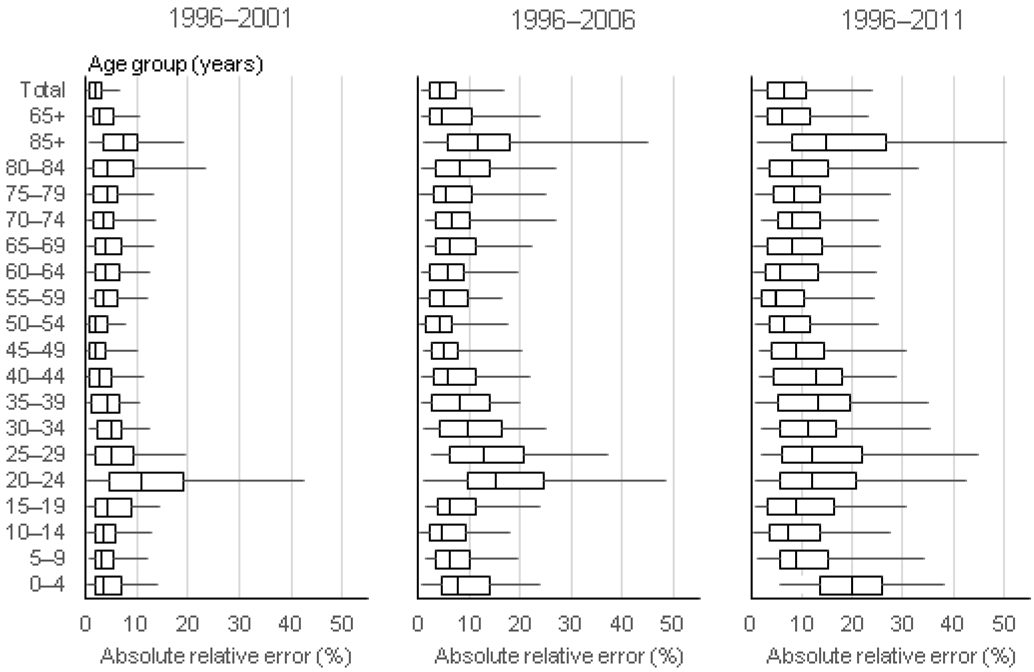
Figure 8.13

Absolute relative error distribution of medium population projections
66 territorial authority and 21 Auckland local board areas, 1996–2011
5th, 25th, 50th (median), 75th, and 95th percentiles

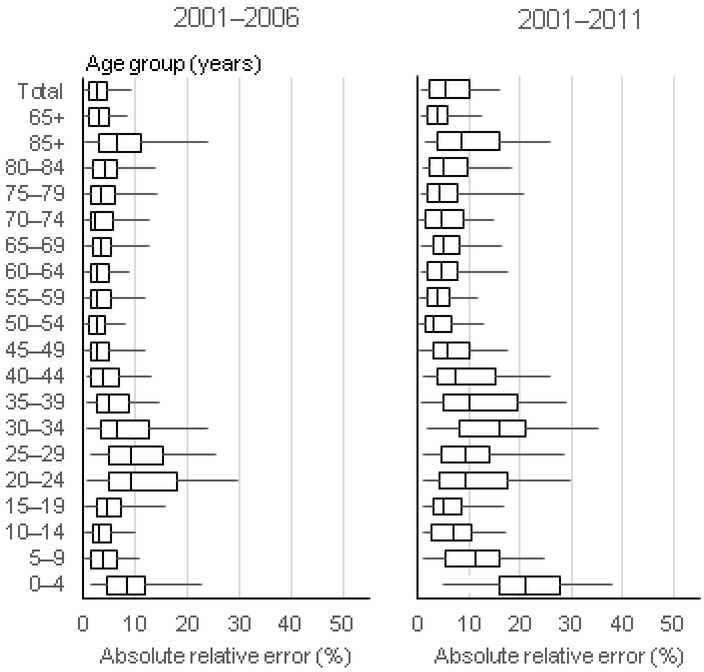
1996-base projections published 1997



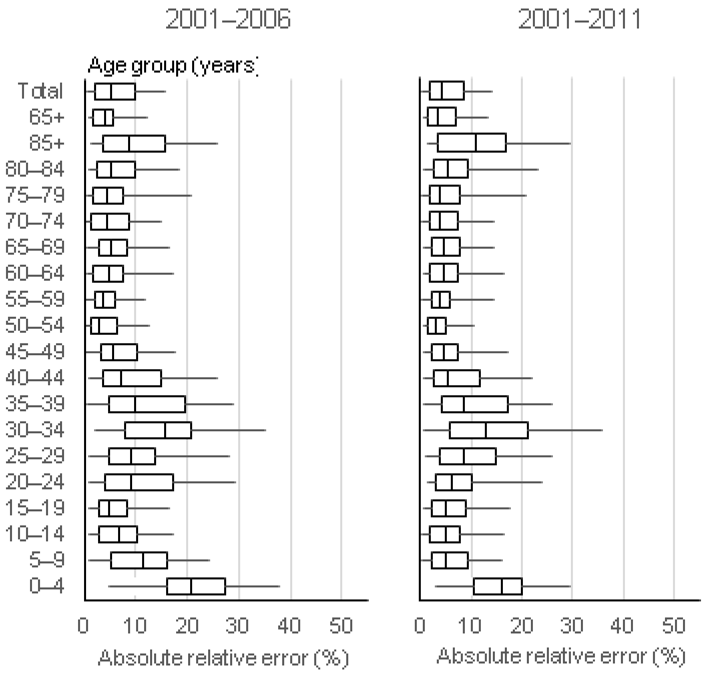
1996-base projections published 2000



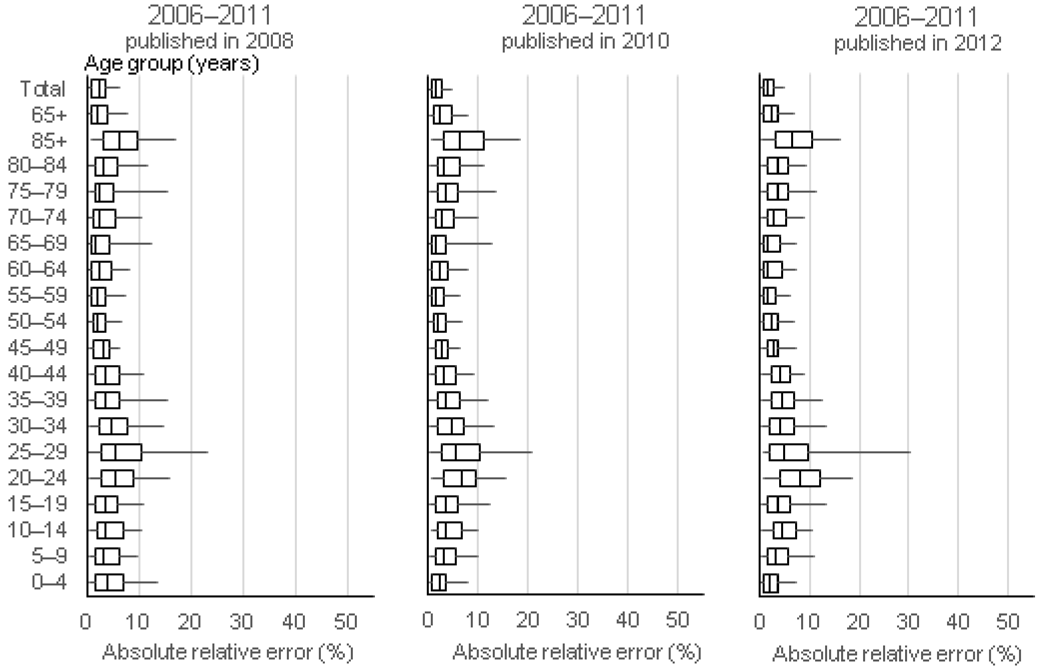
2001-base projections published 2003



2001-base projections published 2005



2006-base projections



Source: Statistics New Zealand

9 Discussion and future work

Accuracy results

In a sense, the results of this evaluation of accuracy are unsurprising. Population estimates and projections generally become more inaccurate as they move away from their base (starting point). They are also generally more inaccurate, in relative terms, for smaller populations (eg disaggregations by geography or age).

It is still useful to quantify the patterns of accuracy, as well as the accuracy results for specific geographic areas. See **Accuracy of estimated and projected populations 1996–2013** (interactive Excel file) under 'Available files'.

Evaluating past accuracy is not merely of retrospective value. Past accuracy also indicates accuracy for current population estimates and projections, which is useful if current measures are unavailable. Also, understanding patterns of accuracy is useful for considering the accuracy of derived measures, such as those using population estimates as a denominator.

Given accuracy tends to deteriorate over time, away from the base, the accuracy results are a useful baseline for questions around how frequent a census should be. This is important as Statistics NZ considers options for a long-term transformation of census (McNally & Bycroft, 2015).

Producers of estimates and projections make improvements to methods to reduce cost (eg reduce resource spent on production) and to enhance quality (eg improve accuracy). The results indicate that accuracy may be increasing for more-recent estimates and projections, but the results are inconclusive based on the limited comparison periods.

Accuracy is not obviously deteriorating for more recent estimates and projections. However, accuracy is partly affected by the prevailing demographic conditions. During periods of rapid population change, such as those resulting from high net migration gains, relative errors tend to be higher.

The evaluation provides evidence that the updates of projections during each intercensal period are more accurate than the initial set of projections. Indeed, this is the aim of such updates – to incorporate more-recent information. This includes updated demographic information (births, deaths, and migration), but can also be non-demographic information, especially at a local (area unit) level (eg planning information, building consents).

This raises the question as to how frequently projections should be updated. With a limited understanding of customers' accuracy requirements (McNally & Bycroft, 2015), the current update and release of projections every 2–3 years appears an appropriate balance, knowing some customers would prefer an annual update while others would be satisfied with an update every five years (after each census).

There are other considerations, such as the resources required to produce and disseminate each set of projections, and the importance of consistency across Statistics NZ's demographic projections. This consistency applies to the additivity of (mid-range) projections across different geographic levels. It also applies to total population, ethnic population, family and household, and labour force projections being consistent with each other.

The most resource-intensive projections are for the existing 2,000+ area units. There will always be a trade-off between making the process as efficient and automated as possible, and incorporating local features in the projection model.

Retaining some flexibility in updating projections might also be important. The 2010–11 Canterbury earthquakes caused demographic disruption in greater Christchurch, as well as accelerating migration flows into neighbouring districts. The earthquakes also caused the cancellation of the 2011 Census. Additional national and subnational projections were produced in 2012, which aimed to reflect the demographic impact of the earthquakes, in the absence of delayed census information.

Customers who use Statistics NZ’s estimates and projections should understand from this accuracy evaluation the importance of using the latest available estimates and projections. Estimates get revised in the light of new information, especially when new census data allows subnational population estimates to be recalibrated. Projections get updated following the availability of new population estimates and other demographic data.

No-one should make decisions using estimates and projections that have been superseded by new information. In addition, while this assessment of past accuracy indicates the magnitude and pattern of future inaccuracies, there is no inevitability about the direction (under or over) of those future inaccuracies.

Future methodological work

Statistics NZ's earlier evaluation of projection accuracy (2008) identified several avenues for future work. One was to develop measures of uncertainty – the flipside of accuracy – through stochastic or probabilistic projections. A working paper on this methodological development (Dunstan, 2011) preceded official stochastic projections of the New Zealand population (Statistics NZ, 2012b, 2014b) and labour force (Statistics NZ, 2012a, 2015c).

Since then, stochastic projections have been produced for New Zealand’s major ethnic populations (Statistics NZ, 2015b). Applying a stochastic approach to subnational projections is more challenging, but statistical models are being developed (Bryant & Graham, 2013). These stochastic approaches explicitly identify the inherent uncertainty in projections and help manage expectations around accuracy.

Statistical models also facilitate more disaggregated projections. For example, instead of producing subnational projections in five-year steps and for five-year age groups, projections could be derived in one-year (annual) steps and for single years of age.

Without explicit stochastic measures of uncertainty, conventional deterministic projections convey uncertainty qualitatively – through alternative scenarios. Given the accuracy results presented here, widening the range given by ‘low’ and ‘high’ growth projections is an option. For subnational projections, that means having a wider range between the low and high net migration assumptions, although not wide enough to limit the usefulness of low and high projections for customers.

The 2008 report also identified post-censal population estimates as a critical input into projections accuracy. In particular, the report recognised the following limitations of classifying passenger type to ‘permanent and long-term’ (PLT) or ‘short-term’ largely from passengers’ responses on arrival/departure cards (to the question on intended or actual length of stay/absence).

- Actual duration of stay/absence could be quite different to that intended.
- For people who move in and out of New Zealand many times each year, their passenger type may be unclear to the travellers themselves, and in the processing of migration statistics.
- Incomplete/incorrectly completed passenger cards can cause incorrect classification.

Generally, PLT migration is a good if imperfect indicator of the contribution of external migration to changes in New Zealand’s resident population. However, in 2001–06 it was notably an under-estimate (see Migration). Because of the limitations, alternative migration measures are being investigated by linking arrival and departure records to determine actual stay and absence time, independent of passengers’ statements (either intended or stated). Potentially, this better measures the contribution of external migration to changes in New Zealand's resident population.

Ideally, net migration, if estimated in population estimates and modelled in population projections, would be disaggregated into its component flows: external arrivals, external departures, internal arrivals, and internal departures. Current Statistics NZ work (eg Bryant & Graham, 2013) is geared to this development, although existing data sources are limited in their ability to meet the need for disaggregated data by both geography and age.

As with any alternative methods, model reality and practical utility need a balance (Bell & Wilson, 2004). This includes balancing usefulness and the dimensions of statistical quality (Quality dimensions) with costs, complexity, and transparency for both customers and producers of the projections. Other considerations include how applicable alternative methods are to different geographic levels (New Zealand, TAs, area units) and sub-populations (eg ethnic populations).

Internal migration within New Zealand remains the most-difficult population dynamic to measure. There is no data source that gives comprehensive annual measures of these flows. Statistics NZ has investigated numerous data sources (Statistics NZ, 2011, 2013) and now makes more use of primary health organisation enrolment and Inland Revenue tax data, in particular for subnational population estimates.

The Integrated Data Infrastructure (IDI) (Statistics NZ, nd b) provides more potential for identifying internal migration, although its main issues are coverage and timeliness (eg lags between migration and identification in the IDI). In particular, the highly mobile age group 15–24 years has relatively low coverage in the IDI.

The census, the cornerstone of population estimates and projections, is also recognised as a critical data source (Bycroft, 2006). Census strategies are designed to maximise census coverage (participation in the census) and response (valid answers to the census questionnaire). These strategies remain important even though census processes are being modified and potentially transformed (Statistics NZ, 2012d).

A common element among these developments is that anything that affects the accuracy of population estimates will inevitably affect the accuracy of population projections.

Glossary and abbreviations

Absolute error (AE). The difference, irrespective of sign (positive or negative), between the estimated/projected population and observed population in a given year.

Absolute relative error (ARE). The percentage difference, irrespective of sign (positive or negative), between the estimated/projected population and observed population in a given year relative to the observed population.

ALBA. Auckland local board area.

Assumption. A statement about a future course of behaviour (eg fertility, mortality, migration) from which demographic projections (eg of population) are derived.

AU. Area unit.

Average annual population change. An annualised population growth rate calculated as a constant annual rate of population change over the stated period (ie assuming geometric growth rates to allow for compounding growth).

Base population. The starting population, usually distributed by age and sex, from which population estimates and projections are derived.

Census usually resident population count. A count of all people who usually live in a given area, and are present in New Zealand, on a given census night. The census usually resident population count of New Zealand excludes visitors from overseas and excludes New Zealand residents who are temporarily overseas.

For a subnational area the count excludes visitors from overseas and elsewhere in New Zealand (people who do not usually live in that area), but includes residents of that area who are temporarily elsewhere in New Zealand on census night (people who usually live in that area but are absent).

Cohort component method. A method of estimating or projecting the population by updating the size of each age-sex group in the base population, for deaths and migration within each age-sex group, during the period between the base date and a given date. New birth cohorts result from births between the base date and the given date.

Completed fertility rate (cohort total fertility rate). The average number of live births that a woman born in a particular year has had by the end of her reproductive life.

De facto population concept. A statistical basis for a population in terms of those present in a given area at a given time.

Deterministic projection. A single projection from a given set of assumptions (eg about fertility, mortality, migration).

Error. The difference between the estimated/projected population and observed population in a given year. For population estimates, this is commonly referred to as the **intercensal discrepancy**.

Estimate. An indication of the historical demographic characteristics (size and composition) of population, families, households, or labour force, typically using recorded data.

Statistics NZ's population estimates are produced using data from the most-recent Census of Population and Dwellings, updated for estimates of the components of demographic change (births, deaths, and net migration) since that census.

Estimated de facto population. An estimate of all people present in a given area at a given date. The estimated de facto population of New Zealand includes all people present in New Zealand and counted by the census (census night population count). This estimate includes visitors from overseas who are counted on census night, but excludes New Zealand residents who are temporarily overseas. This estimate includes no adjustment for net census undercount.

For a subnational area the estimate includes visitors from overseas and elsewhere in New Zealand (people who do not usually live in that area), but excludes residents of that area who are temporarily elsewhere on census night (people who usually live in that area but are absent).

The estimated de facto population at a given date after census includes births, deaths and net migration (arrivals less departures) of people during the period between census night and the given date.

Estimated resident population (ERP). An estimate of all people who usually live in a given area at a given date. The estimated resident population of New Zealand includes all residents present in New Zealand and counted by the census (census usually resident population count), residents who are temporarily overseas (who the census does not attempt to count), and an adjustment for residents missed or counted more than once by the census (net census undercount). Visitors from overseas are excluded.

For a subnational area the estimate excludes visitors from overseas and elsewhere in New Zealand (people who do not usually live in that area), but includes residents of that area who are temporarily elsewhere on census night (people who usually live in that area but are absent).

The estimated resident population at a given date after census includes births, deaths, and net migration (arrivals less departures) of residents during the period between census night and the given date.

Forecast. A single prediction of what the population will be at a given date.

Intercensal. The period between census dates. More generally it can refer to the period between census years (eg between population estimates at 30 June of one census year and 30 June of the next census year).

Intercensal discrepancy. The difference between population estimates produced before the census and population estimates rebased after the census. It is a measure of the accuracy of population estimates, and is the net combined effect of various factors including inaccuracies in:

- the census counts at the beginning and end of the period
- the adjustments to derive population estimates (from census counts) at the beginning and end of the period
- the components of population change (births, deaths, migration) during the period.

Inter-ethnic mobility. People changing their ethnic identification over time. This may reflect a person's cultural affiliations changing over time. Or it may occur when different people respond to the ethnicity question. For example, the ethnicity of babies and young children is usually identified by their parents. However, in a later census when these children are old enough to complete their own forms, they decide which ethnicity they identify with. This may differ from the ethnicity identified by their parents. Inter-ethnic mobility can also occur when different ethnicities are reported for a person in different collections (eg birth registrations, death registrations, census).

Net census undercount (NCU). The difference between undercount and overcount. It is usually expressed as a percentage of what should have been the complete count rather than as a percentage of what was counted.

Net migration. The difference between arrivals and departures.

Non-private dwelling. A structure, part of a structure, or group of structures that is used, or intended to be used, for short- or long-term communal or transitory type accommodation. Non-private dwellings are generally available to the public by virtue of employment, study, special need, legal requirement, or recreation. They include institutions and group-living quarters such as hotels, motels, hospitals, retirement homes, prisons, hostels, motor camps, boarding houses, defence barracks, ships, and trains.

Observed population change. Change in population between two dates as measured by census counts or population estimates. Where available, the estimated resident population is used in preference to census counts because the former provides the best available measure of the resident population by including allowances for net census undercount and residents temporarily overseas.

Over-estimate. An estimated population that was higher than the revised or rebased population estimate at the corresponding reference date.

Over-projection. A projected population that was higher than the benchmark population estimate at the corresponding reference date.

Permanent and long-term (PLT) migration. PLT arrivals are people arriving to live in New Zealand for 12 months or more (including permanently), and New Zealanders returning after an absence of 12 months or more overseas. PLT departures are New Zealanders departing for an absence of 12 months or more (including permanently), and people from overseas who are departing after a stay of 12 months or more in New Zealand.

The classification of passengers to ‘permanent and long-term’ (or ‘overseas visitor’ or ‘New Zealand-resident traveller’) is primarily determined from responses on the arrival and departure cards to questions about how long the person is in or away from New Zealand, and where they are living for 12 months or more.

Projection. An indication of the future demographic characteristics (size and composition) of population, families, households, or labour force based on an assessment of past trends and assumptions about the future course of demographic behaviour (eg fertility, mortality, migration, living arrangement type, labour force participation).

RC. Regional council (region).

Relative error (RE). The difference between the estimated/projected population and observed population in a given year relative to the observed population.

Resident population concept. A statistical basis for a population in terms of those who usually live in a given area at a given time.

Residents temporarily overseas (RTOs). People who usually live in New Zealand but are overseas for a period of less than 12 months. Most RTOs on census night are away on holiday or business and return to New Zealand within a few weeks of departure.

Stochastic (probabilistic) projection. A projection that varies randomly according to the probability distributions of the assumptions (eg about fertility, mortality, migration). Multiple stochastic projections (or simulations) are typically summarised by percentiles to indicate the distribution of values (eg projection results).

TA. Territorial authority (cities and districts).

Total fertility rate (TFR). The average number of live births that a woman would have during her life if she experienced the age-specific fertility rates of a given period (usually a year). It excludes the effect of mortality. It is derived from the sum of the age-specific fertility rates relating to a given year, and subject to annual fluctuations in births. While they represent each year's experience, they do not necessarily represent the lifetime reproductive experience of real generations or cohorts of women.

Under-estimate. An estimated population that was lower than the revised or rebased population estimate at the corresponding reference date.

Under-projection. A projected population that was lower than the benchmark population estimate at the corresponding reference date.

References

Alho, J M (1997). Scenarios, uncertainty and conditional forecasts of the world population, *Journal of the Royal Statistical Society, 160*(1), 71–85.

Australia Productivity Commission (2005). Economic implications of ageing in Australia. Retrieved from www.pc.gov.au.

Australian Bureau of Statistics (2009). ABS data quality framework. Retrieved from www.abs.gov.au.

Bell, M, & Skinner, J (1992). Forecast accuracy of Australian subnational population projections. *Journal of the Australian Population Association, 9*(2), p207–235.

Bell, M, & Wilson, T (2004). Comparative empirical evaluations of internal migration models in subnational population projections. *Journal of Population Research, 21*(2), 127–160.

Bryant, J, & Graham, P (2013). Bayesian demographic accounts: Subnational population estimation using multiple data sources. *Bayesian Analysis, 8*(3), 591–622.

Bryant, J, Dunstan, K, Graham, P, Matheson-Dunning, N, Shrosbree, E, & Speirs, R (2016). Measuring uncertainty in the 2013-base estimated resident population. Statistics NZ working paper 16–04. Retrieved from www.stats.govt.nz.

Bycroft, C (2006). Challenges in Estimating Populations. *New Zealand Population Review, 32*(2), 21–47.

Chomik, R (2015). The back-to-the-future fact sheet: a visual history of demographic projections in Australia. Centre of Excellence in Population Ageing Research. Retrieved from www.cepar.edu.au.

Wang, C-L (2002). Evaluation of Census Bureau's 1995-2025 State Population Projections, Population Division Working Paper Series No. 67, Population Division, US Census Bureau. Retrieved from www.census.gov.

Dion, P, & Galbraith, N (2015). Back to the future: A review of forty years of population projections at Statistics Canada. *Canadian Studies in Population*, 42,102–116. Retrieved from https://ejournals.library.ualberta.ca.

Dunstan, K (2011). Experimental stochastic population projections for New Zealand: 2009(base)–2111. Statistics New Zealand Working Paper 11–01. Retrieved from www.stats.govt.nz.

Harper, G, Coleman, C, & Devine, J (2002). Evaluation of 2000 subcounty population estimates. Population Division, US Census Bureau. Retrieved from www.census.gov.

Howe, A (1998). Issues in estimating small area populations. Demography Working Paper 98/1, Australian Bureau of Statistics. Retrieved from www.abs.gov.au.

Keilman, N (1997). Ex-post errors in official population forecasts in industrialized countries. *Journal of Official Statistics, 13*(3), 245–277.

Keilman, N (2007). UK national population projections in perspective: How successful compared to those in other European countries? *Population Trends, 129*, 20–30.

Lunn, D, Simpson, S, Diamond, I, & Middleton, L (1998). The accuracy of age-specific population estimates for small areas in Britain. *Population Studies, 52,* 327–344.

McNally, J, & Bycroft, C (2015). Quality standards for population statistics: Accuracy requirements for future census models. Retrieved from www.stats.govt.nz.

OECD (2016). OECD.Stat. Retrieved from http://stats.oecd.org.

Office of National Statistics (2013). Guidelines for measuring statistical output quality. Retrieved from http://webarchive.nationalarchives.gov.uk.

Office of National Statistics (2015a). National population projections accuracy report. Retrieved from www.ons.gov.uk.

Office of National Statistics (2015b). Subnational population projections accuracy report. Retrieved from www.ons.gov.uk.

Shaw, C (2007). Fifty years of United Kingdom national population projections: how accurate have they been? *Population Trends, 128,* 8–23.

Smith, S, & Tayman, J (2003). An evaluation of population projections by age. *Demography, 40*(4), 741–757.

Smith, S, Tayman, J, & Swanson, D (2001). State and local population projections. New York: Kluwer Academic.

Statistics Canada (2002). Statistics Canada's Quality Assurance Framework. Retrieved from www.statcan.ca.

Statistics NZ (2007). Principles and protocols for producers of Tier 1 statistics. Retrieved from www.stats.govt.nz.

Statistics NZ (2008).How accurate are population projections? An evaluation of Statistics New Zealand population projections, 1991–2006. Retrieved from www.stats.govt.nz.

Statistics NZ (2011). Evaluation of alternative data sources for population estimates. Retrieved from www.stats.govt.nz.

Statistics NZ (2012a). National labour force projections: 2006(base)–2061 (August 2012 update). Retrieved from www.stats.govt.nz.

Statistics NZ (2012b). National population projections: 2011(base)–2061. Retrieved from www.stats.govt.nz.

Statistics NZ (2012c). Statement of Intent 2012–17. Wellington: Statistics New Zealand. Retrieved from www.stats.govt.nz.

Statistics NZ (2012d). Transforming the New Zealand Census of Population and Dwellings: Issues, options, and strategy. Retrieved from www.stats.govt.nz.

Statistics NZ (2013). Evaluation of administrative data sources for subnational population estimates. Retrieved from www.stats.govt.nz.

Statistics NZ (2014a). Estimated resident population 2013: Data sources and methods. Retrieved from www.stats.govt.nz.

Statistics NZ (2014b). National population projections: 2014(base)–2068. Retrieved from www.stats.govt.nz.

Statistics NZ (2015a). Local population trends. Retrieved from www.stats.govt.nz.

Statistics NZ (2015b). National ethnic population projections: 2013(base)–2038. Retrieved from www.stats.govt.nz.

Statistics NZ (2015c). National labour force projections: 2015(base)–2068. Retrieved from www.stats.govt.nz.

Statistics NZ (nd a). Demographic projections. Retrieved from www.stats.govt.nz.

Statistics NZ (nd b). Integrated Data Infrastructure. Retrieved from www.stats.govt.nz.

Statistics NZ (nd c). National population estimates. Retrieved from www.stats.govt.nz.

Swanson, D, Tayman, J, & Barr, C (2000). A note on the measurement of accuracy for subnational demographic estimates. *Demography, 37*(2), 193–201.

Wilson, T (2007). The forecast accuracy of Australian Bureau of Statistics national population projections. *Journal of Population Research, 24*(1), p91–117.

Wilson, T, & Rowe, F (2011). The forecast accuracy of local government area population projections: a case study of Queensland. *Australasian Journal of Regional Studies, 17*, 204–243.

Woods, C, & Dunstan, K (2014). Forecasting mortality in New Zealand (Statistics New Zealand Working Paper No 14–01). Retrieved from www.stats.govt.nz.

Appendix 1: Relative error of projections by average annual population change, territorial authority and Auckland local board areas, 1996–2011

The figures presented here illustrate the patterns of relative error in projections against the observed average annual population change (from census-based population estimates) for different projections during 1991–2011, and for different geographic areas: 66 territorial authority (TA) areas (ie excluding Auckland) and 21 Auckland local board areas (ALBAs), a total of 87 areas plus New Zealand for comparison.

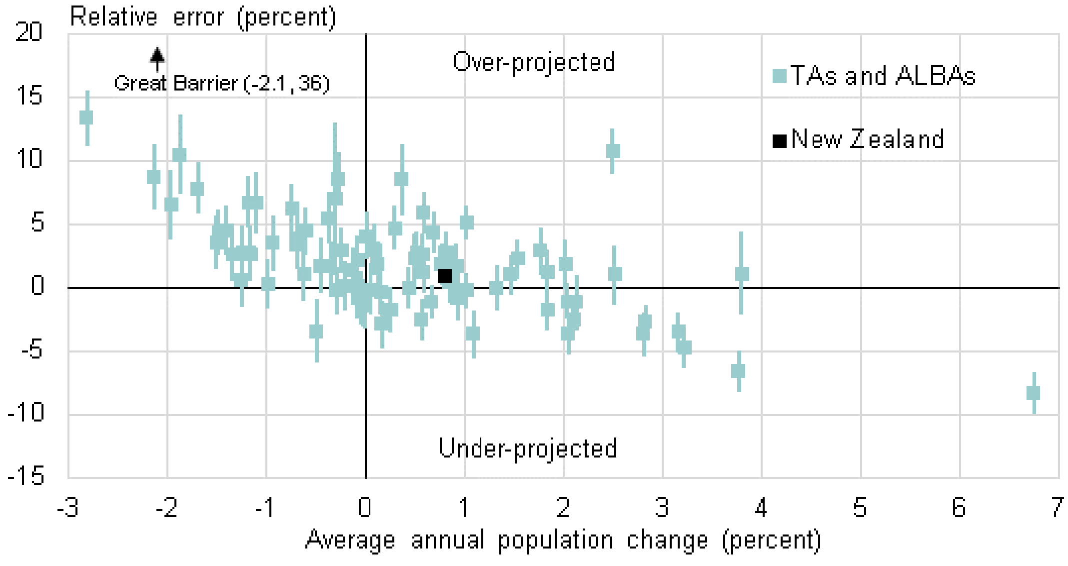
In each figure, each data point represents the relative error of the published medium (mid-range) projections against actual (observed) annualised population change for each period. The bars below and above each data point represent the relative error of the published 'low' and 'high' projections, respectively. If the medium projection was identical to the observed population (ie relative error = 0), then each data point would straddle the horizontal axis, with the bars extending below and above the axis. In practice, some areas are under-projected and some are over-projected. The figures therefore illustrate the extent to which the low, medium, and high projections indicated the actual (observed) population.

Several general patterns are evident in the figures.

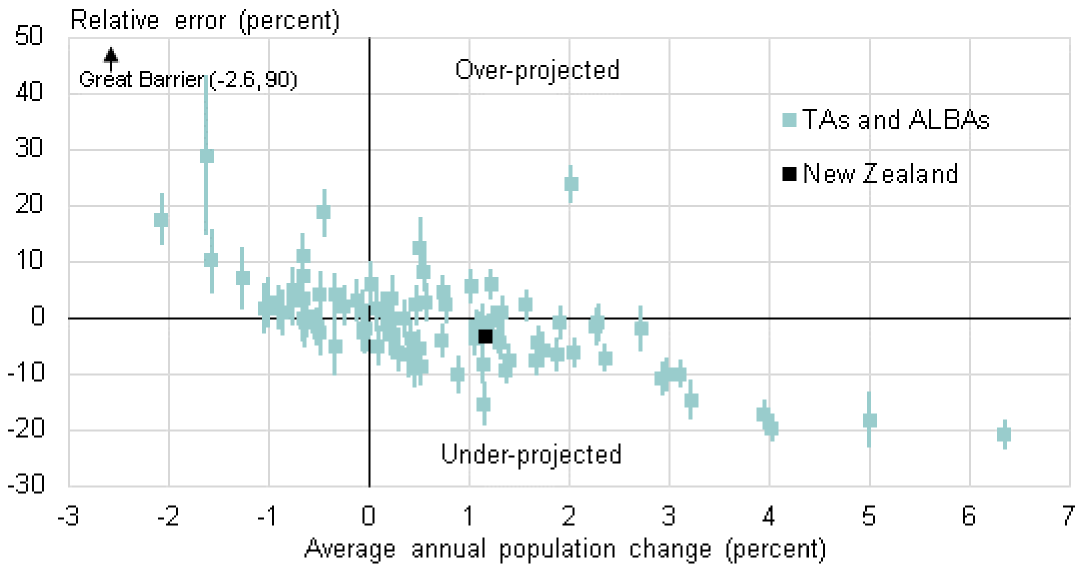
- A tendency for the fastest growing areas to be under-projected and the slowest growing (or declining) areas to be over-projected.
- Relative errors tend to increase in range as the projection period increases.
- Relative errors tend to increase in range as the size of the geographic areas decreases.

Appendix figure 1: Relative error of projections by average annual population change, territorial authority and Auckland local board areas, 1996–2011

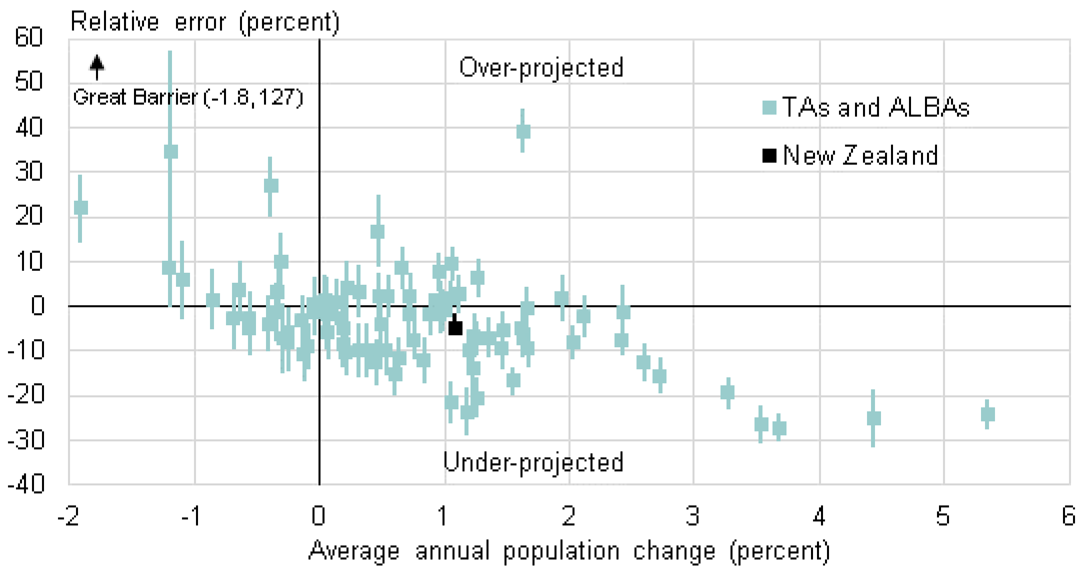
Period 1996–2001, 1996-base projections published 1997



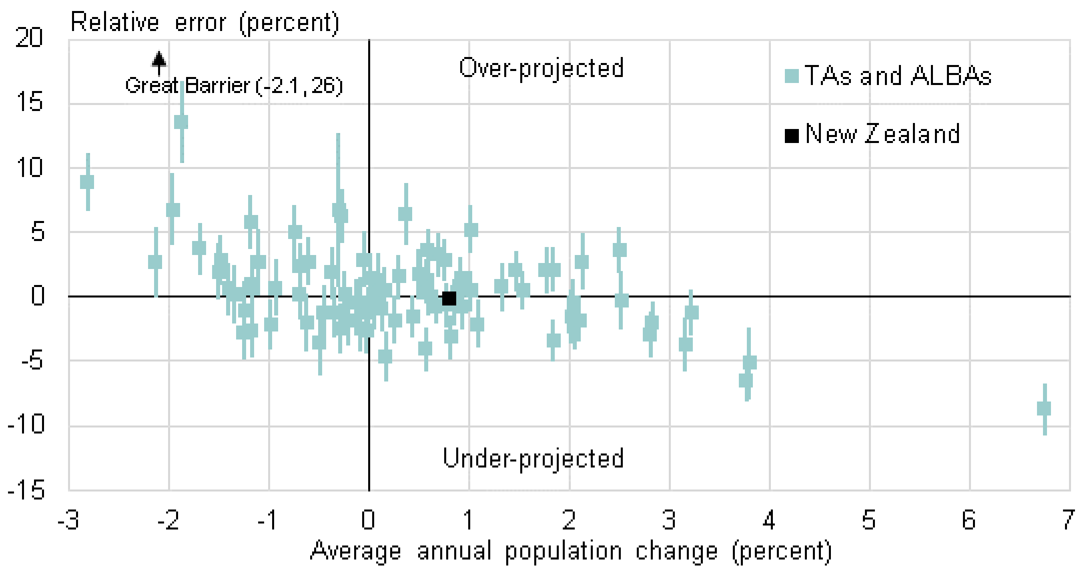
Period 1996–2006, 1996-base projections published 1997



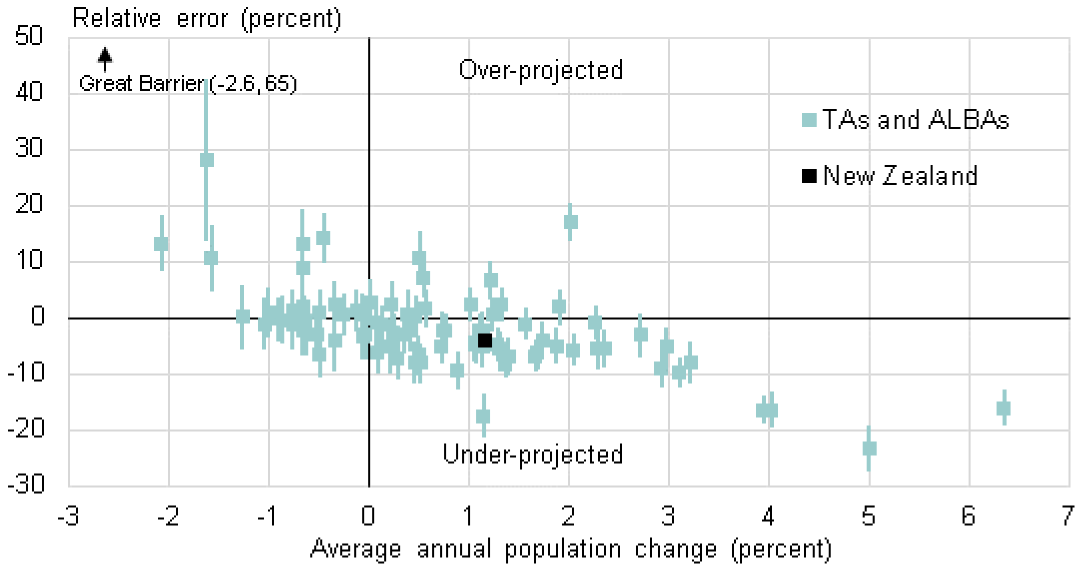
Period 1996–2011, 1996-base projections published 1997



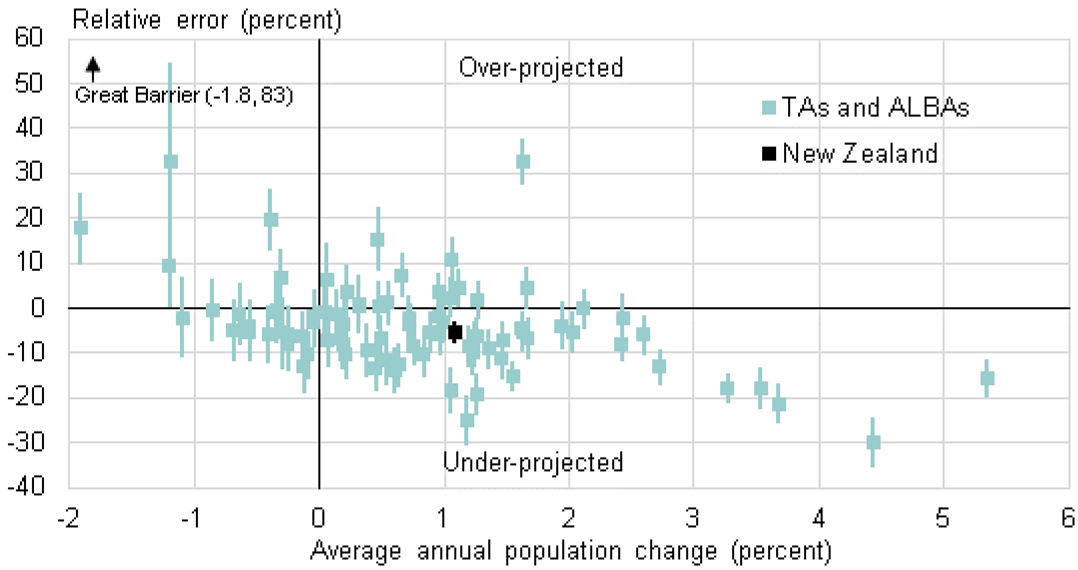
Period 1996–2001, 1996-base projections published 2000



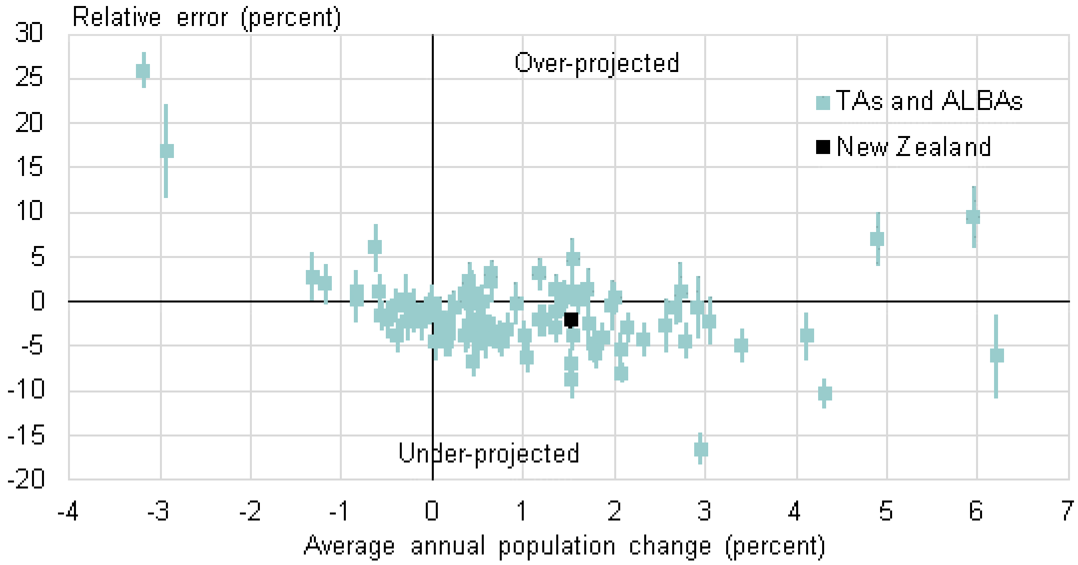
Period 1996–2006, 1996-base projections published 2000



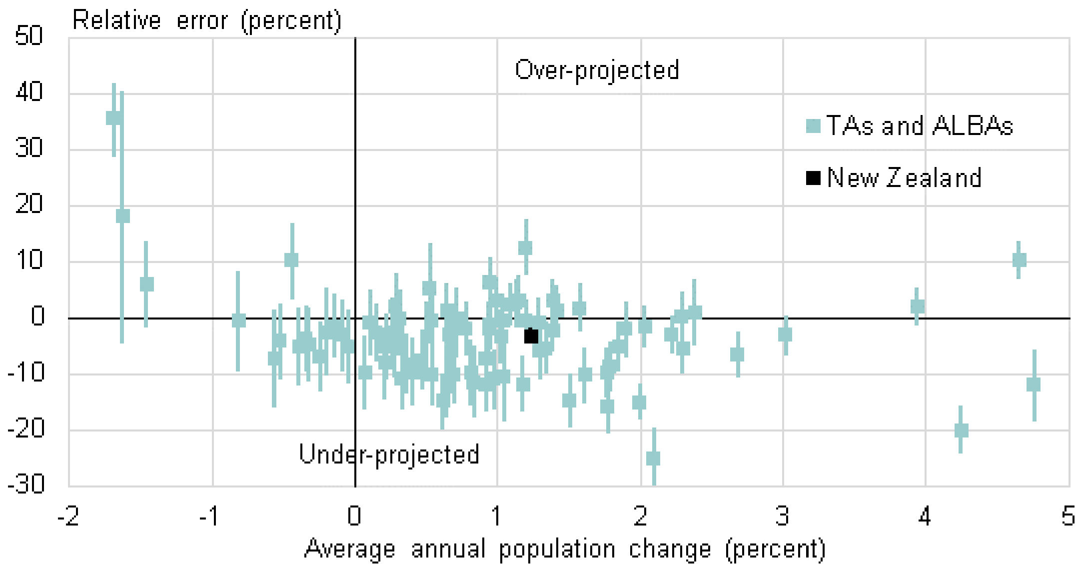
Period 1996–2011, 1996-base projections published 2000



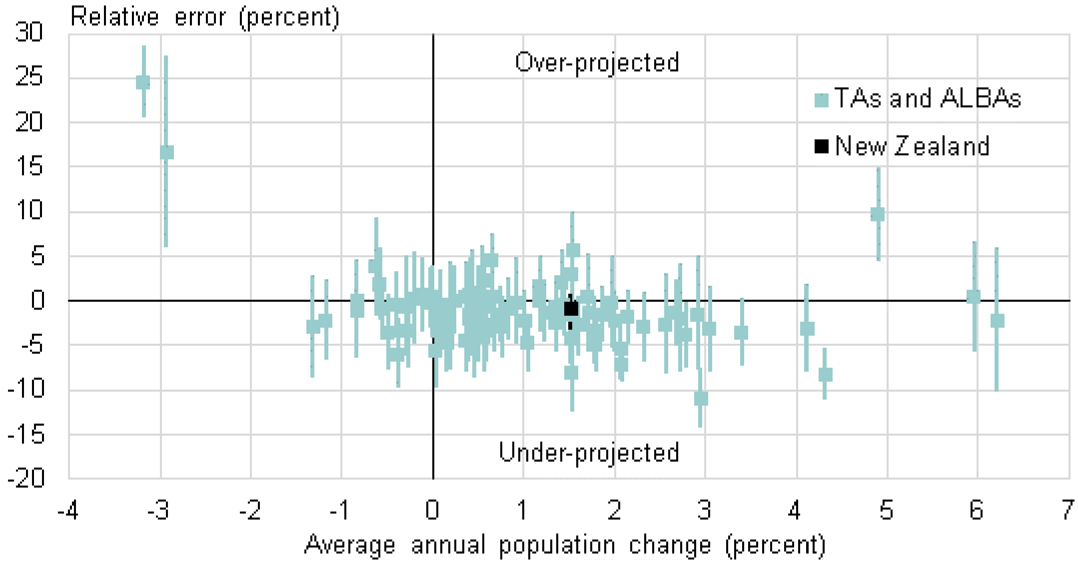
Period 2001–2006, 2001-base projections published 2002



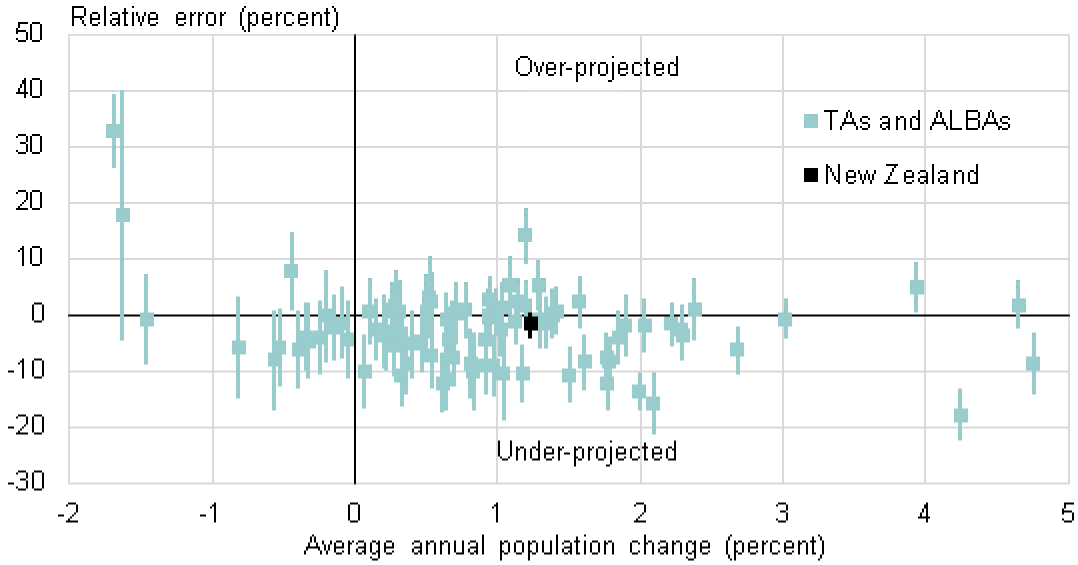
Period 2001–2011, 2001-base projections published 2002



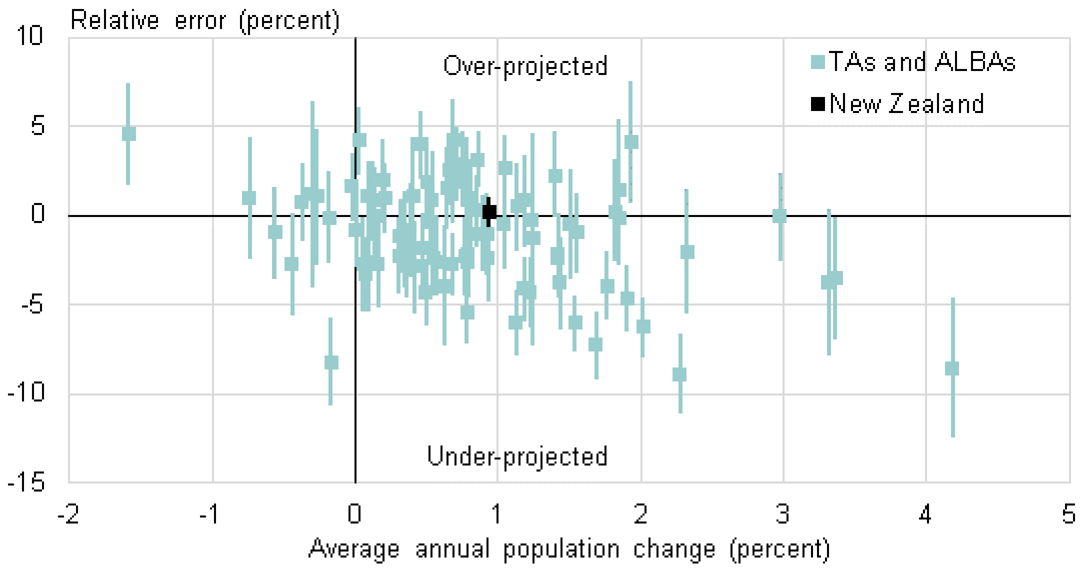
Period 2001–2006, 2001-base projections published 2005



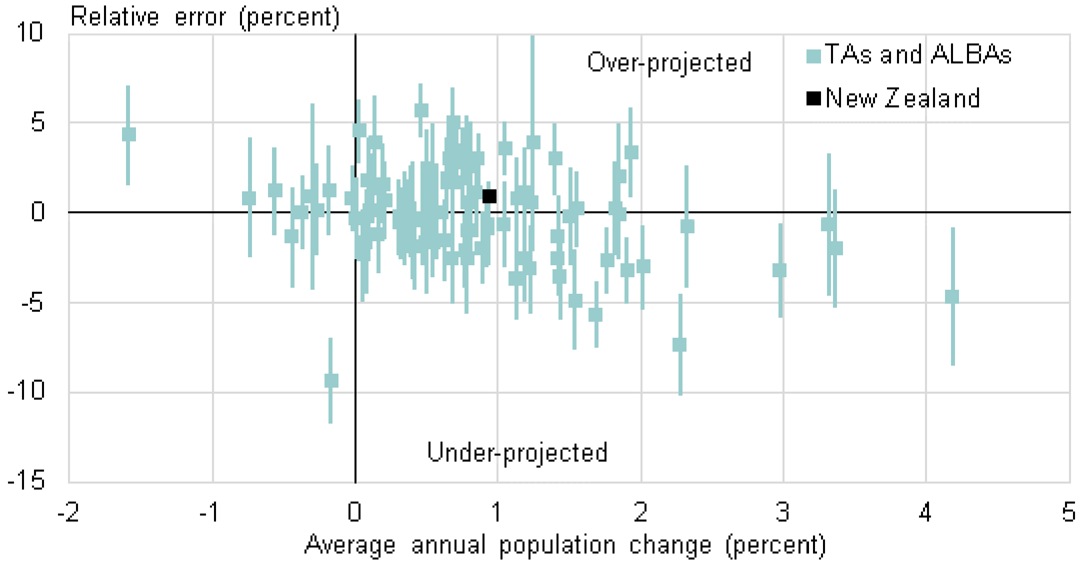
Period 2001–2011, 2001-base projections published 2005



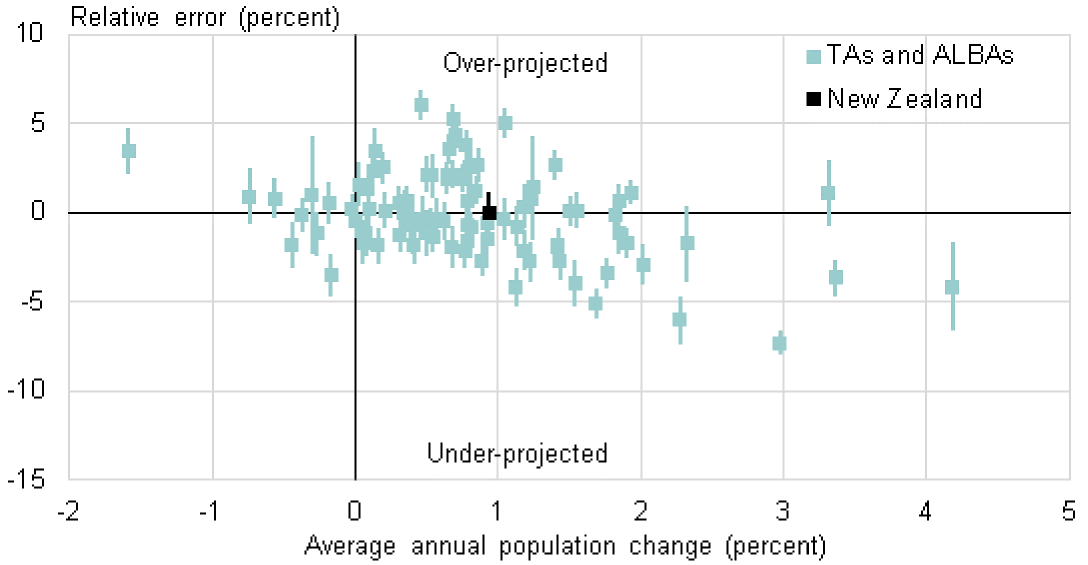
Period 2006–2011, 2006-base projections published 2007



Period 2006–2011, 2006-base projections published 2010



Period 2006–2011, 2006-base projections published 2012



Source: Statistics New Zealand

Appendix 2: Relative error of projections by average annual population change, area units with 100+ population, 1996–2011

The figures presented here illustrate the patterns of relative error in projections against the observed average annual population change (from census-based population estimates) for different projections during 1996–2011, for area units with at least 100 people.

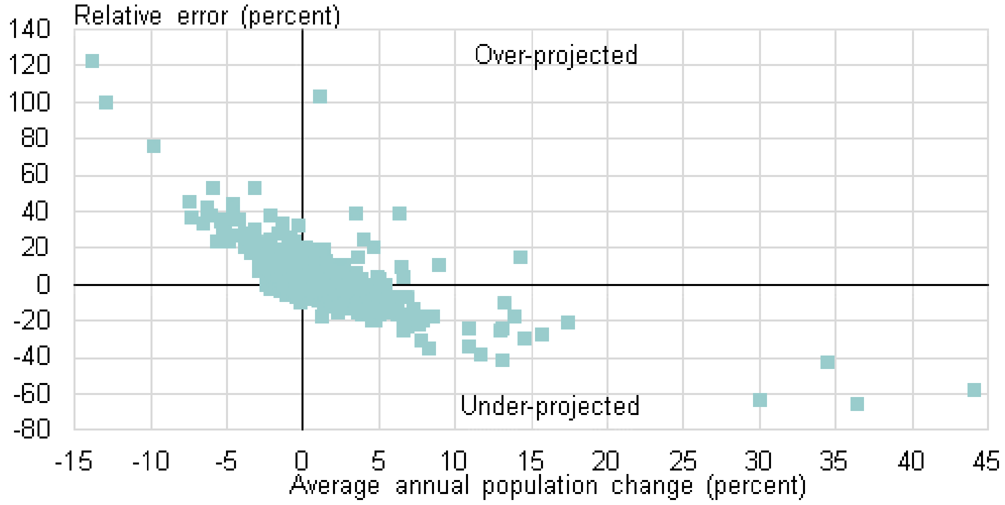
In each figure, each data point represents the relative error of the published medium (mid-range) projections against actual (observed) annualised population change for each period. If the medium projection was identical to the observed population (ie relative error = 0), then each data point would lie along the horizontal axis. In practice, some areas are under-projected and some are over-projected. The figures therefore illustrate the extent to which the medium projections indicated the actual (observed) population.

Several general patterns are evident in the figures.

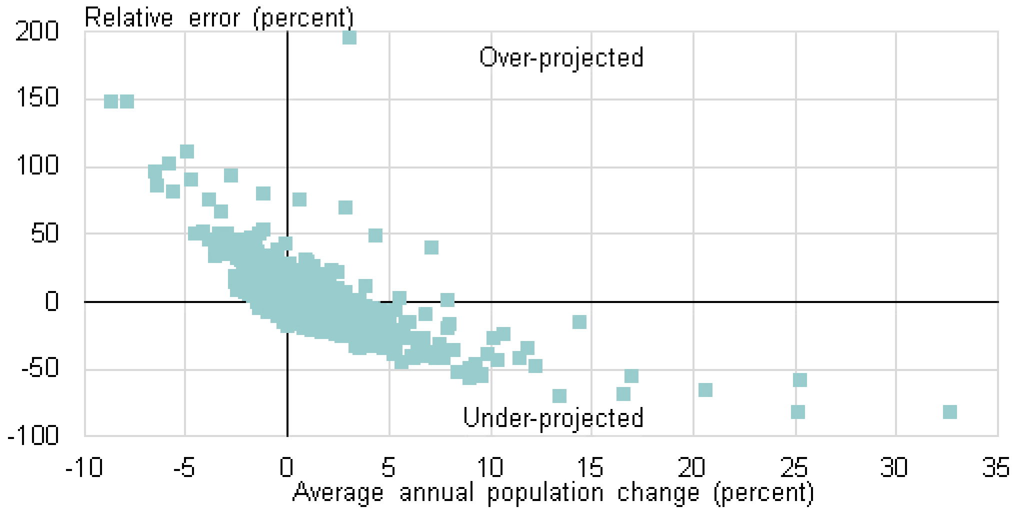
- A tendency for the fastest growing areas to be under-projected and the slowest growing (or declining) areas to be over-projected.
- Relative errors tend to increase in range as the projection period increases.

Appendix figure 2: Relative error of projections by average annual population change, area units with 100+ population, 1996–2011

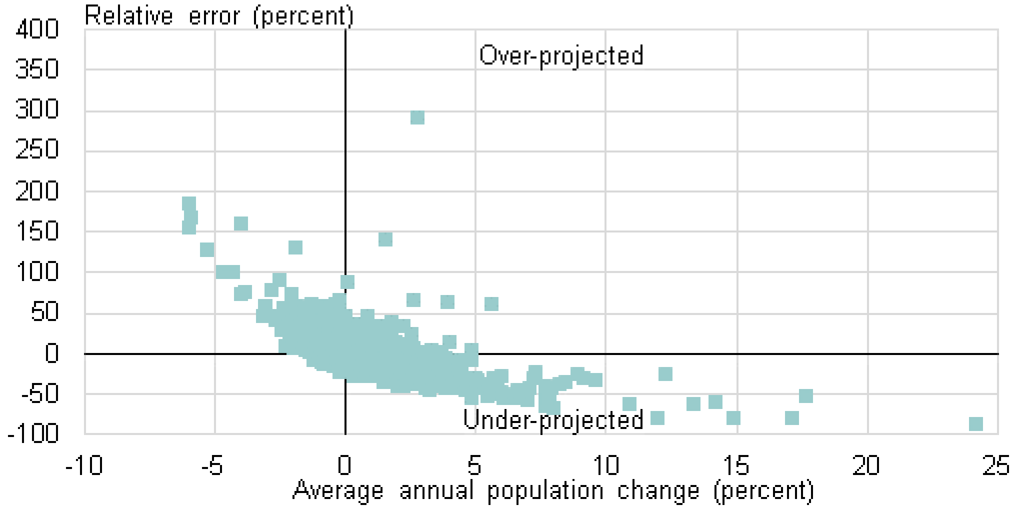
Period 1996–2001, 1996-base projections completed 1997



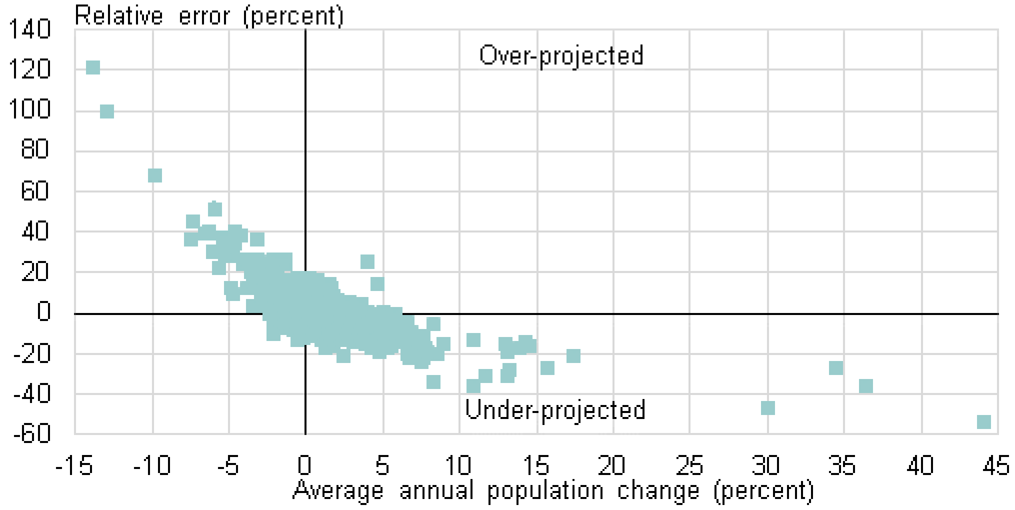
Period 1996–2006, 1996-base projections completed 1997



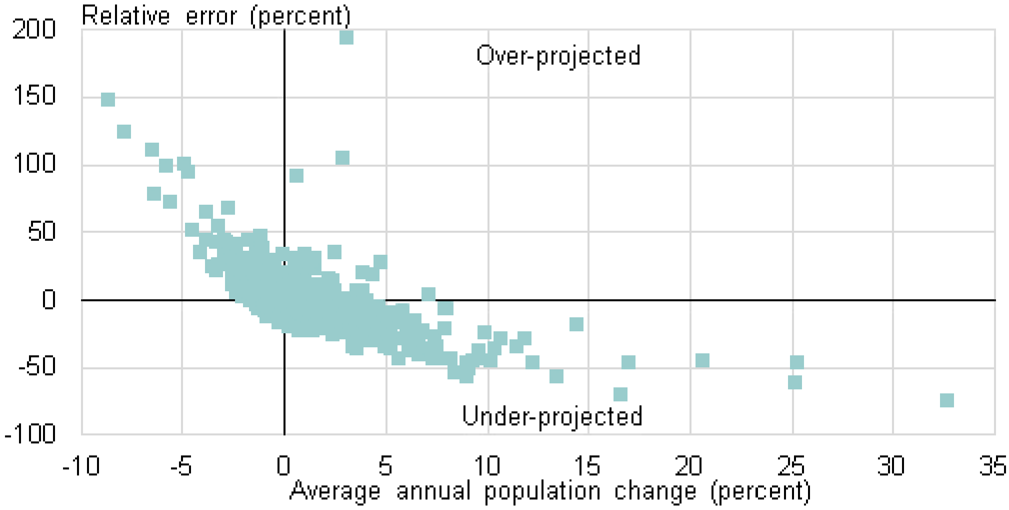
Period 1996–2011, 1996-base projections completed 1997



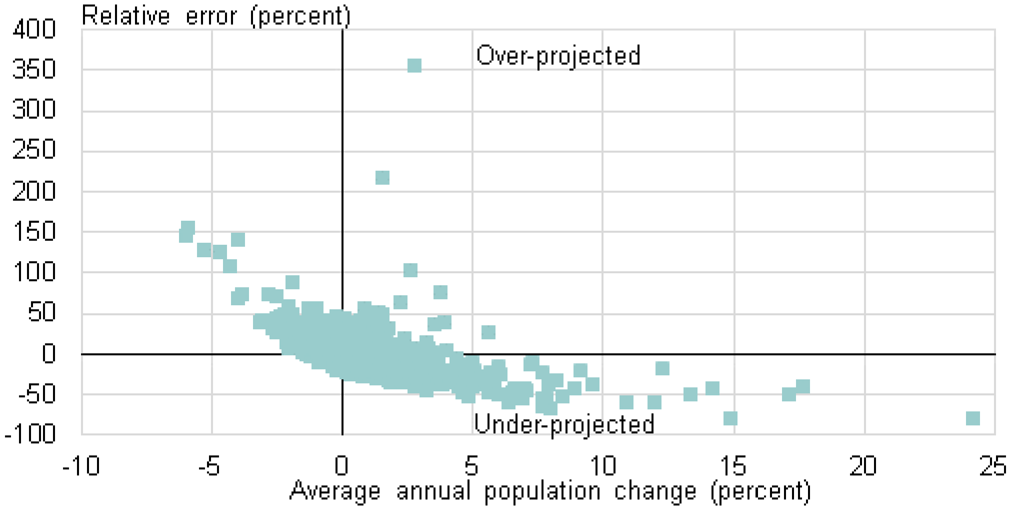
Period 1996–2001, 1996-base projections completed 2000



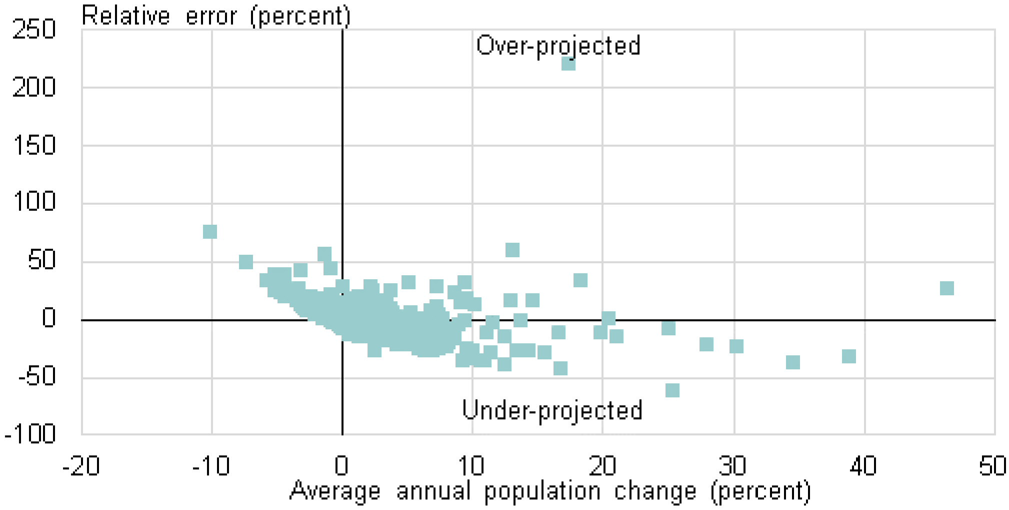
Period 1996–2006, 1996-base projections completed 2000



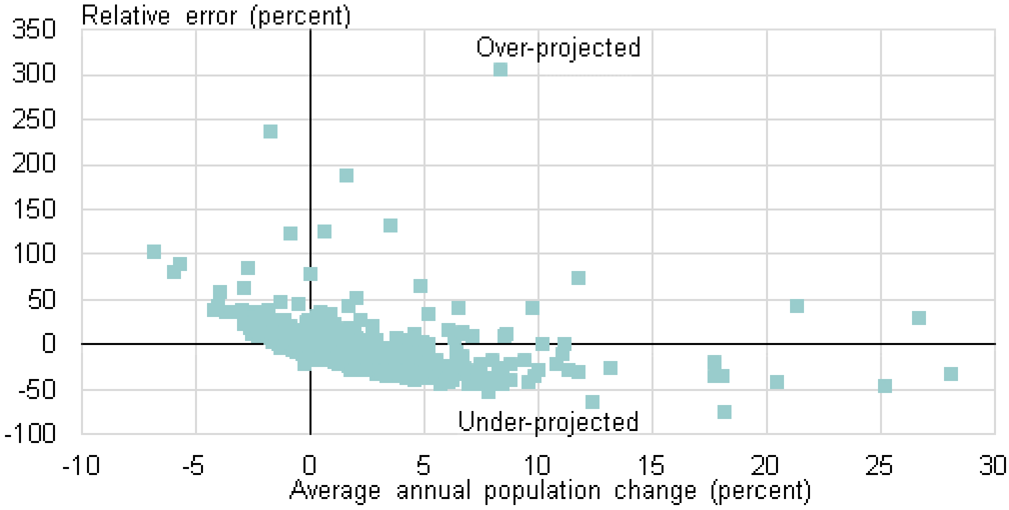
Period 1996–2011, 1996-base projections completed 2000



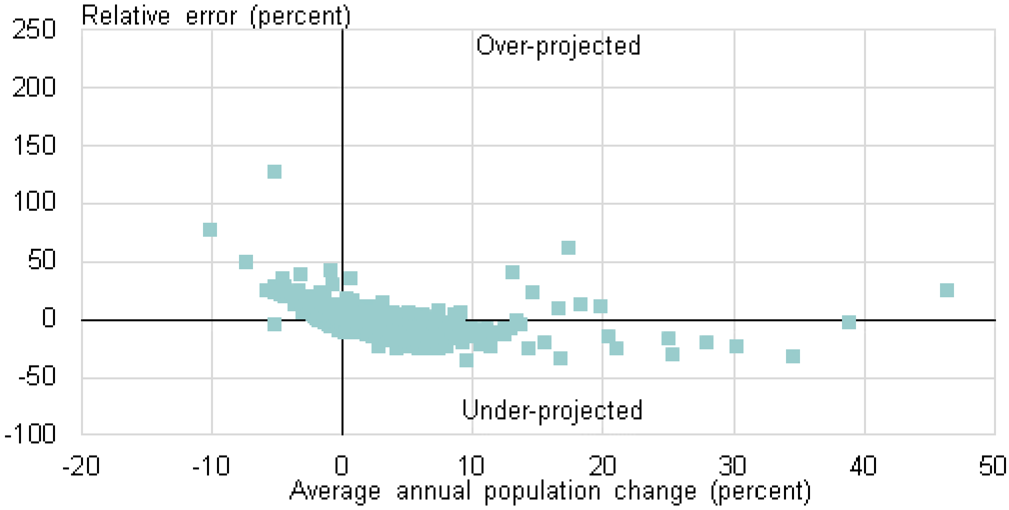
Period 2001–2006, 2001-base projections completed 2003



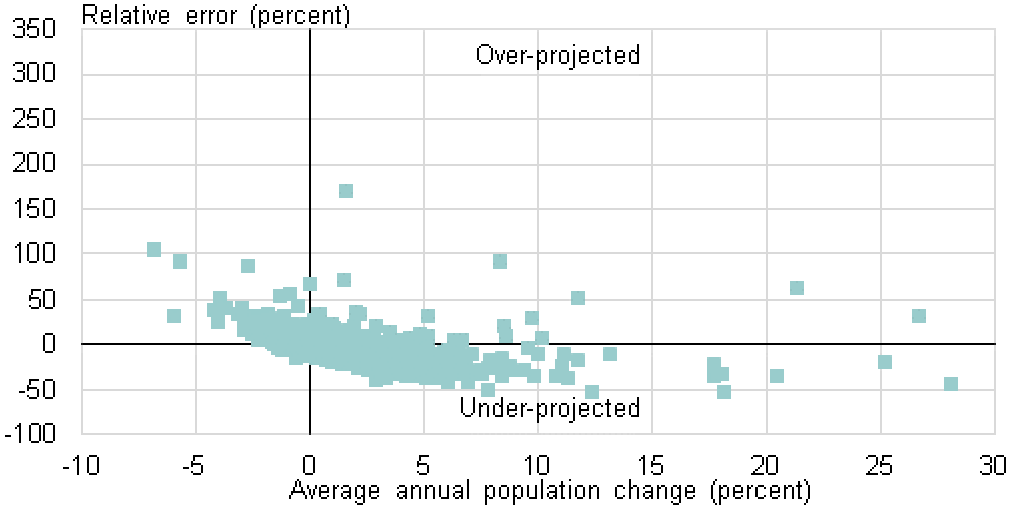
Period 2001–2011, 2001-base projections completed 2003



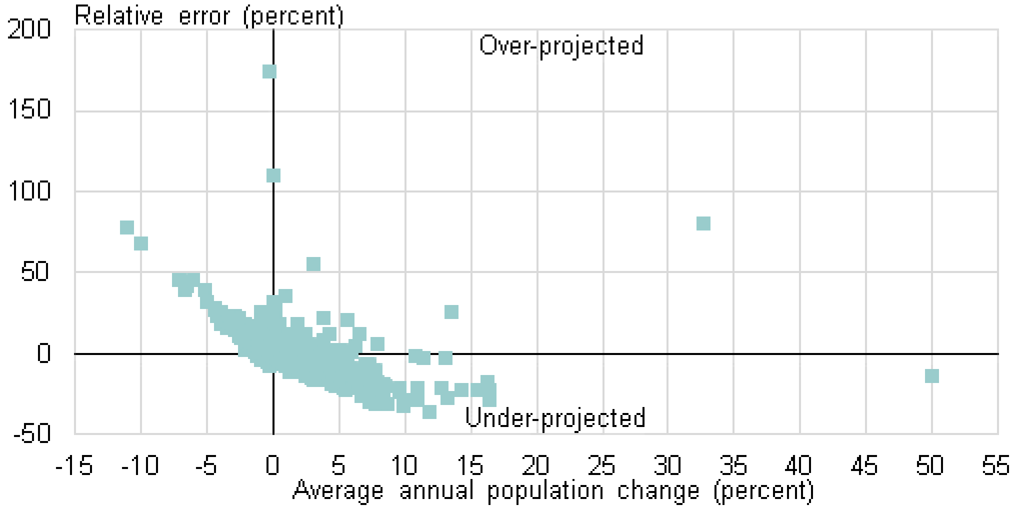
Period 2001–2006, 2001-base projections completed 2005



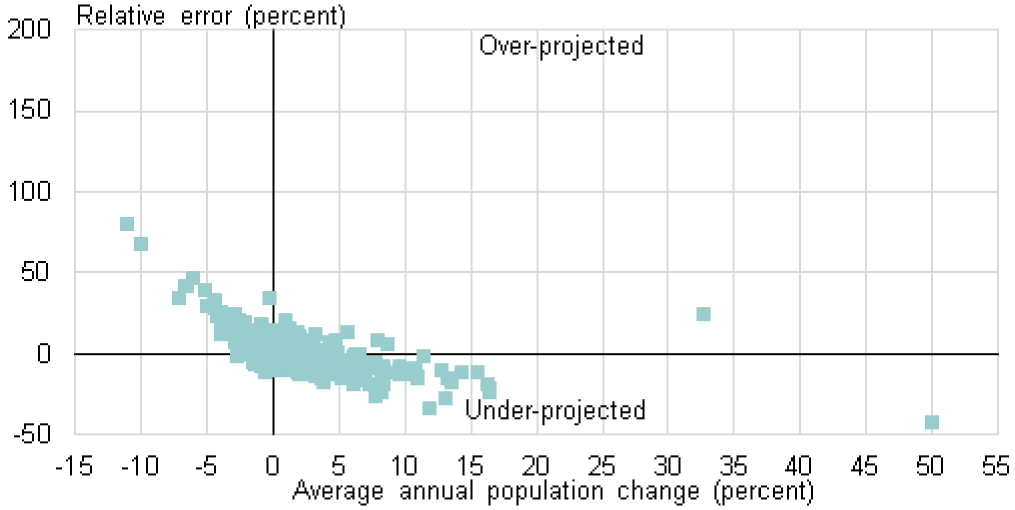
Period 2001–2011, 2001-base projections completed 2005



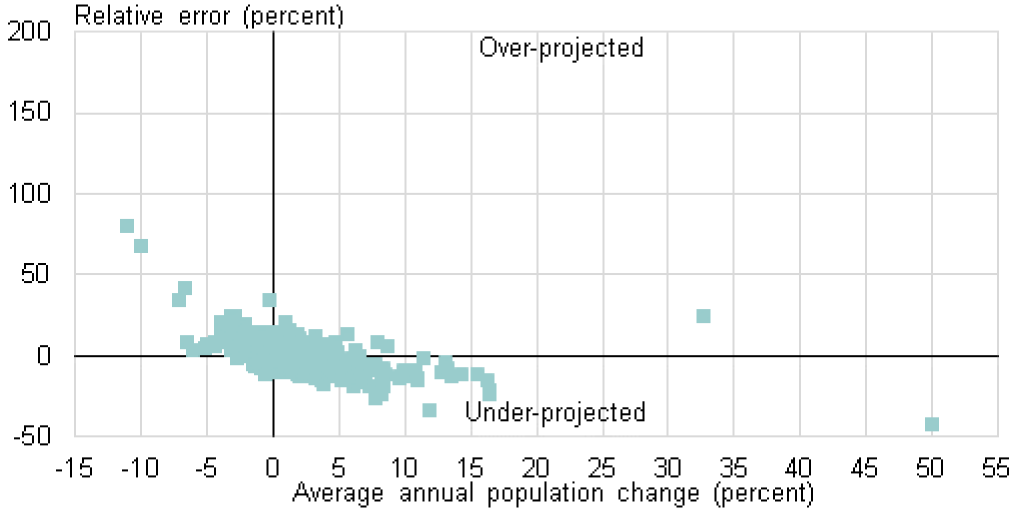
Period 2006–2011, 2006-base projections completed 2008



Period 2006–2011, 2006-base projections completed 2010



Period 2006–2011, 2006-base projections completed 2012



Source: Statistics New Zealand