

Research Brief

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Population Projections in Sparsely Populated Areas: Reconciling ‘error’ and context

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RESEARCH AIM

This study aims to examine issues around ‘fit-for-purpose’ for the application of population projections to remote contexts.

The focus is on population projections made for the Northern Territory of Australia to assess the relative accuracy of projections over time.

Note: readers may require background reading on statistical methods including temporal autocorrelation.

KEY FINDINGS

- There are substantial difficulties in compiling projections of populations residing in sparsely populated areas like the Northern Territory. Approaches to developing and utilising projections should be different for these populations to better understand demographic and other related issues.
- ABS projections are the main source of information about the likely future size and composition of the Territory’s population but these are shown to be relatively inaccurate within a short period from the initial (jump-off) year.
- Measures of absolute accuracy in the ABS projections for the NT showed the tendency for projecting a greater population than actually eventuates, and for the significant under or over estimation from scenarios with many instances of the middle series exhibiting high absolute errors.
- The magnitude of over estimation for the total NT population was around a quarter of the eventual population in just 20-years into the projections.
- There is a positive relationship between projections accuracy and years into projections for the NT’s population with percentage errors (PEs) becoming relatively large within short timeframes.
- Comparisons to other sources of projections for the Territory demonstrate alternative approaches and the importance of the user ‘community’ working with data custodians and residents to better understand the dynamic nature of populations in SPAs.

I. Introduction and Background

Population projections are increasingly important as a resource for policy and program formulation and as tools for understanding and modelling economic, social and environmental futures for sparsely populated areas (SPAs) (Taylor, 2011). This study examines issues around ‘fit-for-purpose’ for the application of projections to SPAs in developed nations. We focus on the Northern Territory to assess the relative accuracy of projections over time as a case example in the SPA context. The results conclusively demonstrate the reduced accuracy of remote population projections. Nevertheless, the exercise of comparing and contrasting the accuracy of projections provides a useful lens for understanding demographic and other issues which necessitate which approaches to developing and utilising projections can and should be different in SPAs. We provide examples of alternative approaches to projections and the analysis of errors for researchers of SPA jurisdictions. This research is published in the International Journal of Population Research, Volume 2014; Article ID 658157 at <http://dx.doi.org/10.1155/2014/658157>.

In Sparsely Populated Areas (SPAs - or remote areas) of developed nations the demand for systematic understanding about likely population growth and change is no less than for other jurisdictions, despite their share of national populations invariably being small (Taylor 2011). This reflects contemporary interest in Indigenous affairs, resource based industries for national economic production and perceived opportunities for future national economic prosperity from ‘northern development’ agendas; all common themes in the political agenda for ‘northern’ parts of developed nations (Carson, 2011).

The characteristics of populations residing in SPAs across the globe underscores the substantial difficulties in compiling projections (Baerenholdt & Granas, 2008; Carson et al., 2011). Specifically, a small stock of knowledge on the demographic composition of SPA populations in Canada, Australia, Sweden, Norway, Russia, Lapland, Finland and Alaska has emerged to document relationships between historical demography, contemporary population characteristics and the economies of SPAs. An interleaved theme is the application of standard tools and techniques for understanding past, current and future demographic change may provide limited perspectives (Tayman, Swanson & Barr, 1999; Carson et al., 2011). The reasons span the gamut of social, economic and political influences that have recently been summarised in a conceptual framework titled the ‘8D’s of remote demography’ (Carson et al., 2011). This lays out the key features of populations in SPAs which differentiate them from rural, regional or peri-urban populations. An example is the ‘Dynamic’ nature of SPA populations which are subject to fundamental structural change on occasion (for example, large swings in sex ratios) over a very short time period. These sometimes result from ‘black swan’ events (i.e. extreme weather events), but sometimes major demographic changes cannot be sourced to immediately identifiable causes (Carson et al., 2011).

Demographers and others charged with developing population projections aim to compile a series of numbers at one point in time that are the best approximation of the future population size and composition for a given geographic area. Projections are usually made for several decades out from the initial year (called the jump-off year). The most commonly used projections come under

the label of ‘deterministic’ whereby a set of assumptions about the starting population, migration, fertility and mortality are made and the model determines the number of births, deaths and additions to the population during each year based on pre-determined algorithms. The most commonly used deterministic method is the cohort-component model (Smith, Tayman & Swanson, 2001) which is widely used by governments for planning purposes.

All population projections are subject to a degree of inaccuracy from a combination of imperfect understandings about recent and future fertility, mortality and migration behaviours in tandem with imperfect data for generating projection assumptions (Wilson, 2007). In demographic terms, errors in projections are measured as differences between the projected and eventual populations. For these reasons, demographers often provide information to help users determine the applicability and likely accuracy of projections – or ‘fit for purpose’. It is also common to produce a range of ‘series’ or scenarios to demonstrate how variations in assumed fertility, mortality or migration settings might affect population size and composition into the future (for example, Australian Bureau of Statistics (ABS), 2013).

In compiling projections for SPAs, demographers face many additional challenges. Not least, the collection and production of demographic data for SPAs are more costly, time consuming and difficult than for elsewhere resulting in reduced confidence in the level of accuracy and completeness of data (Taylor et al., 2011). Research to date on the accuracy of projections for developed nations has almost exclusively focused on national or supra-national regions where populations are relatively large (for example, Wilson, 2007). These and other empirical studies are conclusive insofar as three general principles have emerged:

1. Accuracy diminishes according to the length of the projection period (or ‘horizon’);
2. Accuracy is inversely related to population size; and
3. The rate of growth during the base period on which projection assumptions are based influences the level of accuracy into the future.

Only isolated examples of research into the accuracy of projections for populations at lower levels exist.

This paper addresses the gap in the contemporary literature on the relative accuracy of population projections for SPAs from which assessments about their applicability and ‘fit for purpose’ can be made. Questions arise, in particular, about the relative scale and the timing of errors (for example, how far into the projections do errors become noticeable for SPAs compared to elsewhere?) and whether systematic improvements in accuracy are observed over time. In this study, we develop a range of indicators on the relative accuracy of population projections for an SPA in the north of Australia as a means of both addressing the absence of any such analysis for SPAs and to demonstrate the value of alternative approaches to projections for SPAs. Other jurisdictions internationally will benefit from adopting and modifying this research to improve their understanding of projections accuracy and ways to improve it over time.

2. The Northern Territory

The Northern Territory (NT) is the least populous of the States and Territories in Australia with just two percent of the national population (233,000) but comprising 18% of the landmass (Geoscience Australia, 2012). Half the population lives in Darwin with the remainder residing in remote settlements. The NT has a significant Indigenous population constituting a third of the total. However, outside of Darwin over half are Indigenous or comprise the vast majority in many settlements. The population of the NT is Australia's youngest, with a median age of 31, some six years lower than the national median (ABS, 2013).

For as far back as records go, the population of the NT has grown in a volatile fashion. Prior to the late 1970s, when it first maintained a population above 100,000, volatility was attributable to its small size. A simplified synopsis of its history emphasises that a range of known and unknown factors impact on demographic research for SPA jurisdictions like the NT. Nevertheless, accurate assessments on current and future population compositions and numbers are critical since the NT's population size determines the number of political seats it holds in the national parliament (Wilson et al., 2005) and the allocation of Goods and Services Tax to the NT under national revenue transfers (Wilkinson, 2003), upon which its economy relies heavily.

Given this context, understanding the size and scope of errors around population projections presents as an important but unfulfilled research task. For places like the NT critical questions include:

- How accurate have ABS projections for the NT been in comparison to Australia?
- What is the extent of bias towards underestimation or overestimation in projections?
- Does evidence exist for systematic improvements in the accuracy of official projections for NT over time?
- Do alternative approaches (like basic naïve modelling), locally developed projections or other alternatives provide more accurate results?
- What might the answers to these questions tell us about developing better projections for SPAs as a collective?

A number of practical outcomes may result from evaluations of projections for SPAs. Firstly, systematic errors in modelling processes or their underlying assumptions may be identified. As well as applying corrections to future forecast techniques, users can be advised of systematic errors and their impacts prevalent in the current set of projections. Secondly, assessments on projection errors assist users to understand the likely accuracy of new forecasts as they come to hand. Codified knowledge of past errors which are non-systematic can help users determine the best application of such data to various tasks and scenarios, including which series (for example, high, low or middle series) to apply (Taylor, 2011). Thirdly, knowledge about errors in projections can assist modellers to calibrate time series models which rely on projections for predicting other demographic trends.

3. Materials and Methods

At any point in time, around 40 ‘live’ series’ of projections for the NT can be in circulation with the majority compiled by the Australian Bureau of Statistics (ABS). In this study we extend Wilson’s (2007) work on the accuracy of population projections at the national level to compare and contrast the accuracy of ABS projections made for the NT and other projections including the NT Department of Treasury and Finance NTPOP model (described in full in Wilson, 2009) and projections compiled by the Australian Department of Health and Ageing (2009). Other than the naïve projection (which use an exponential model holding the average annual growth rate experienced in the previous five years constant), all of these are cohort component models which utilise the population accounting framework:

$$P_t + n = P_t + (B - D) + (M^{\text{in}} - M^{\text{out}}) + (I - E),$$

where P_t = population at time t and n is the population in a subsequent year; B = Births; D = Deaths; M^{in} = Internal in migration; M^{out} = Internal out migration; I = International immigration; and E = International emigration.

The NTPOP model is distinctive because it separately projects Indigenous and non-Indigenous populations as well as allowing for interactions between these cohorts (see Wilson, 2009). The Department of Health and Ageing (DHA) projections were compiled for all Statistical Local Areas in Australia (the commonly used base unit for local demographic analysis) by the ABS on behalf of DHA (2009).

ABS projections are sourced from their publication series 3222.0 (with each of the A, B, C and occasionally produced D) series of projections for the base years (the starting year) of 1970, 1978, 1981, 1984, 1987, 1989, 1993, 1995, 1997, 1999, 2002, 2004, 2006 and 2012 incorporated in the analysis of errors. The middle series (generally the Series B) were used in the analysis of percentage errors. Accuracy was examined by comparing projected populations at the total NT level to the published Estimated Resident Population (ERP – sourced from the ABS publication code 3101.0) at 30th June. The NTPOP and Health and Ageing projections base year was 2006, thus permitting only a preliminary assessment (seven years) of their relative accuracy.

A number of measures of the extent and direction of projection errors were used. The degree of error is expressed as a percentage difference between projected and actual populations to give a measure of relative error. Several measures of relative error are available. Percentage Error (PE) is most commonly used to evaluate forecasts of the total population. But several sets of forecasts may be in existence for any given year for which actual population estimates are available. The Mean Percentage Error (MPE) measurement is an indicator of the type (positive or negative) and extent of bias in a group of projections. The MPE is a measure in which the positive and negative values of errors may be offset. To examine absolute errors associated with a set of forecasts for the total population (ignoring the plus or minus sign), Mean Absolute Percentage Error (MAPE) is used.

Assessments on whether the accuracy of projections for the NT are improving over time were made by comparing the accuracy of projections made within the same decade (1970s, 1980s, 1990s and 2000s). To determine whether differences might represent systematic improvements or declines in projection accuracy or simply instability in the ERP figures, we conducted temporal autocorrelation analysis with lags of 1 to 8 years for each series.

This study is limited in scope to assessing errors against the total NT population as a baseline exploration of projection accuracy in the remote context. Wilson's work in 2009 assessed errors for the components of change which, while outside the scope for this study, is research which should be tackled in the future. In terms of the validity of the measures applied to this study, some demographers have argued for better measures of accuracy. Tayman et al. (1998), for example, proposed that MAPE tends to over-estimate the extent of projection errors and have argued for more widespread use of other approaches. Nevertheless, the MAPE measure was considered appropriate to this study, primarily as a comparator to Wilson's (2007) findings on the accuracy of projections for Australia as a whole.

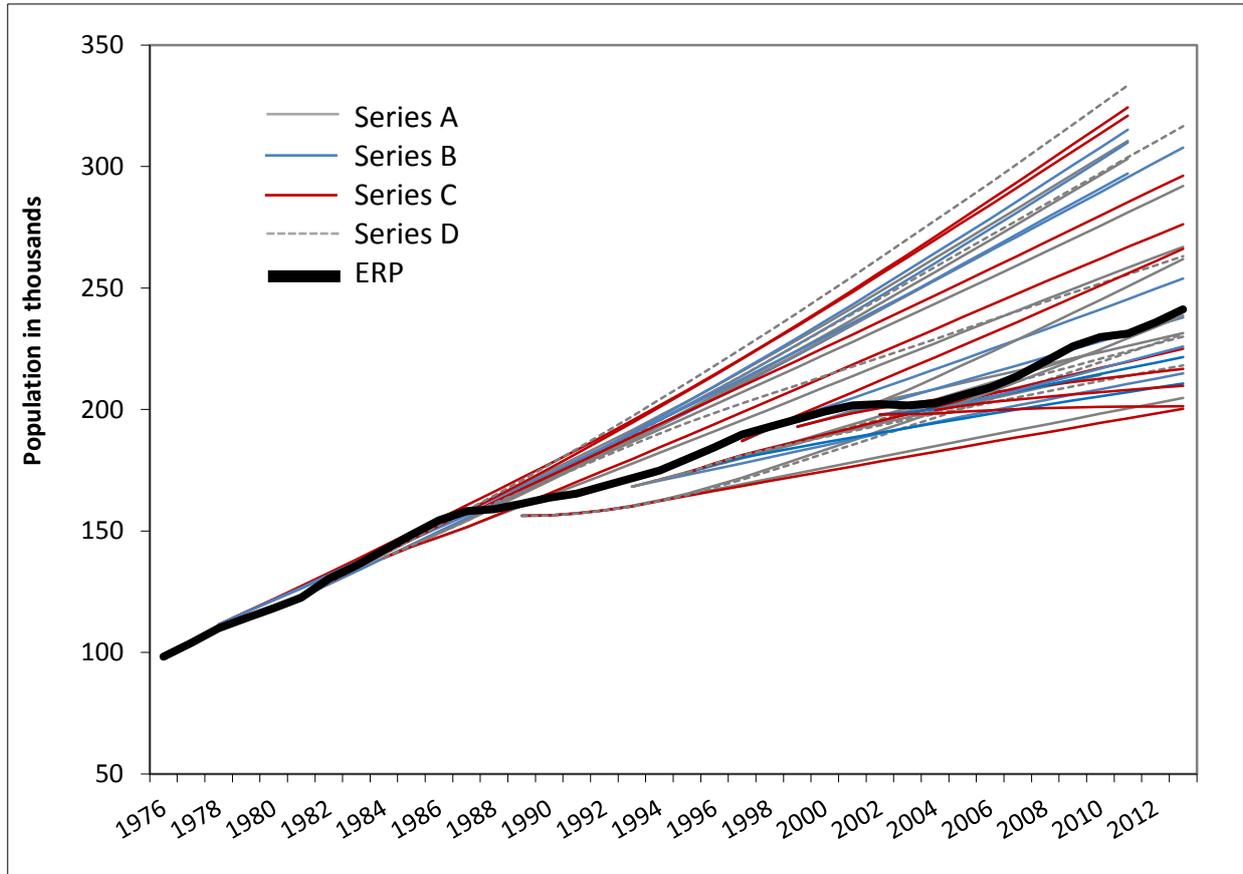
4. Results

4.1 Measures of absolute accuracy in the ABS projections for the NT

4.1.1 Total population

Figure 1 shows the projected total NT population figures from 46 sets of ABS projections from the year 1976 to 2012 in comparison to the actual ERP figures. Of note is the tendency for projecting a greater population than actually eventuates and for the significant under or over estimation from scenarios which incorporate high or low fertility assumptions (that is, generally the A and C or D series). There are nevertheless many instances of the middle (B – blue in Figure 1) series exhibiting high absolute errors. For example, the projected 2010 population from the 1987 B Series was 289,400 when the ERP for 2010 was 229,700 (an absolute error of one quarter).

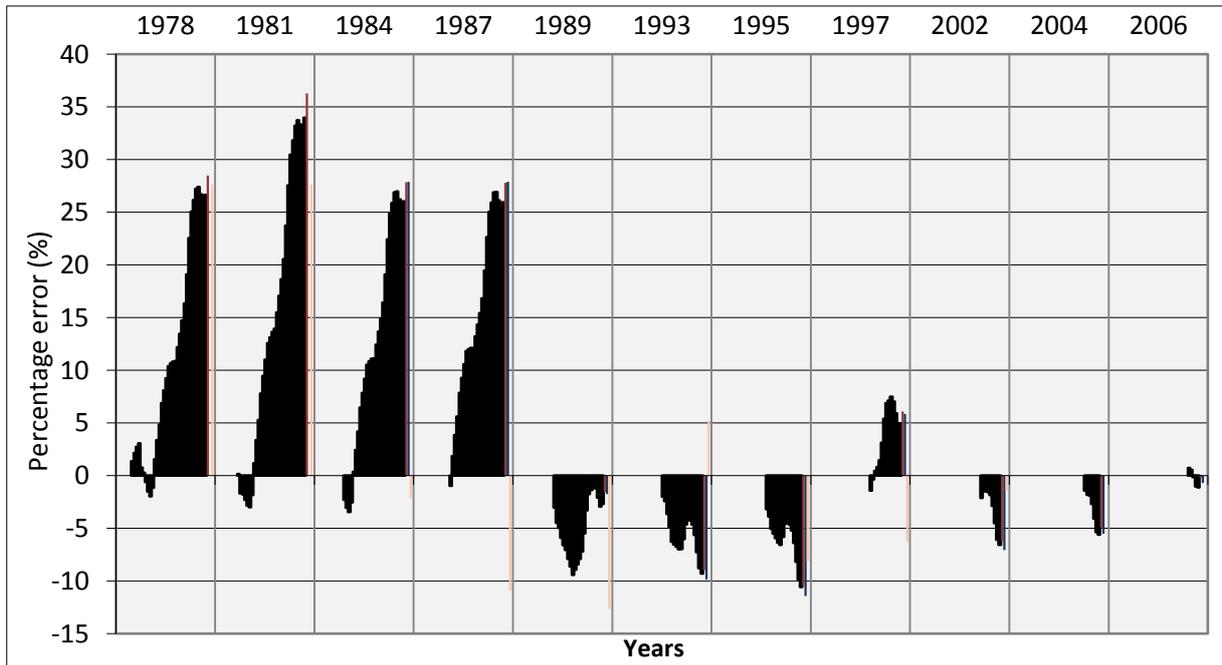
Figure 1. Projected versus actual populations, Northern Territory, 1976 to 2010



4.1.2 Accuracy by years into the projection

Results confirm there is a positive relationship between projection accuracy and years into projections. Figure 2 shows the percentage error (PE) for each year in the B Series ABS projections for the NT. Each column represents the percentage difference (+/-) between the projected population and the ERP for that year. For example, while the PE for the 1981 B Series underestimated the population by around 2.5% for the first few years, it rose to over 36% at the end of 30 years. PEs become relatively large within a short timeframe, for example, the middle series of ABS projections made during the 1980s tended to over - estimate the eventual population by around ten percent within the first ten years.

Figure 2. Percentage by years into projections: ABS B Series

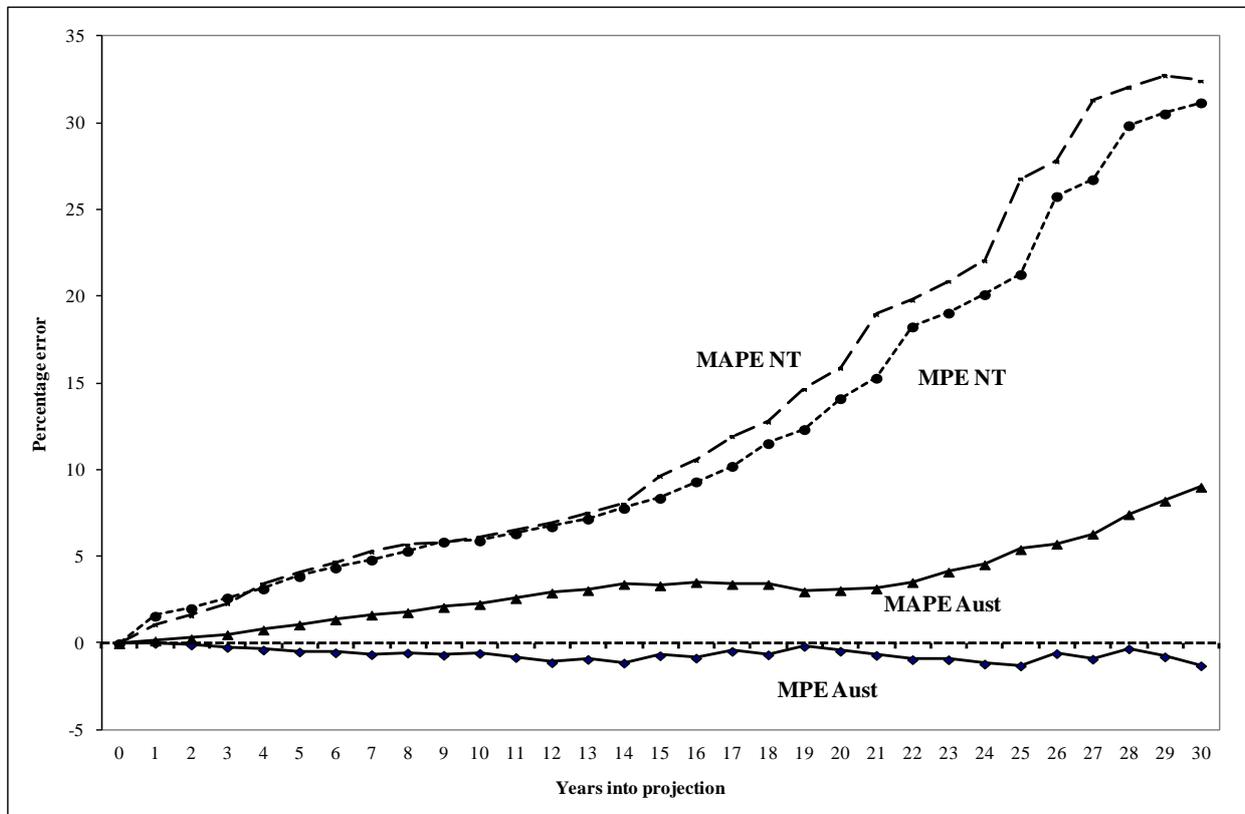


Note: The left bar within each horizontal grid represents the percentage error after the first year of the projections with the base year shown on the Y axis (top)

4.2 The relative accuracy of NT and Australian projections

Comparing the Mean Percentage Error (MPE) for the NT with the MPE of Australia reveals the NT errors were substantially higher across all years of projections (Figure 3). The NT Mean Absolute Percentage Error (MAPE) was more than ten times the Australian MAPE by the first year into the forecast (at 1.69% compared to 0.16%) and then rapidly increased. After two years, the NT MAPE is close to 2.29%, climbing to 6.46% after 10 years into the forecast and 8.72% after 15 years. The MPE for the NT shows the tendency for minor over-estimations up to three years into the projections but relatively large over estimations by ten years into the forecast, while the MPE for Australia shows a small and consistent under-estimation. Where it had occurred, the average level of over-estimation twenty years into the projections was close to a quarter of the actual NT population.

Figure 3. Mean Percentage Error (MPE) and Mean Absolute Percentage Error (MAPE) for middle series ABS projections, 1970s to 2000s



4.3 Evidence for improvements in projections accuracy

To assess whether over time population projections are becoming more or less accurate we compare and contrast the MAPE for the combined projections of each decade. Results show that 1970s and 1980s based projections exhibit similar, relatively high and increasing MAPEs (Figure 4). However, MAPE errors for projections made in the 1990s appear to reduce further-away from the base year. Nevertheless, the MAPE for projections made during the 2000s are comparatively high and appear to be rising as subsequent years of ERPs become available. This is highlighted in Figure 5 which shows the first ten years of MAPE errors for respective decades of projections. It can be seen that 2000s based projections are showing similarly high levels of error to 1980s based projections.

Figure 4. MAPE for individual decades of ABS projections (all series)

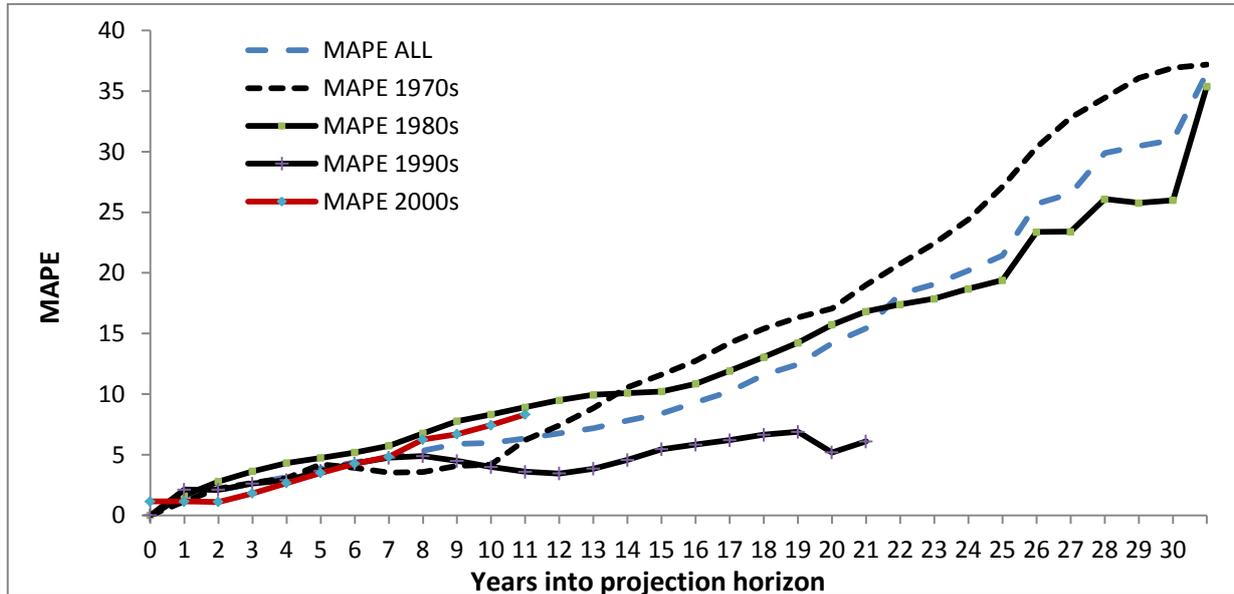
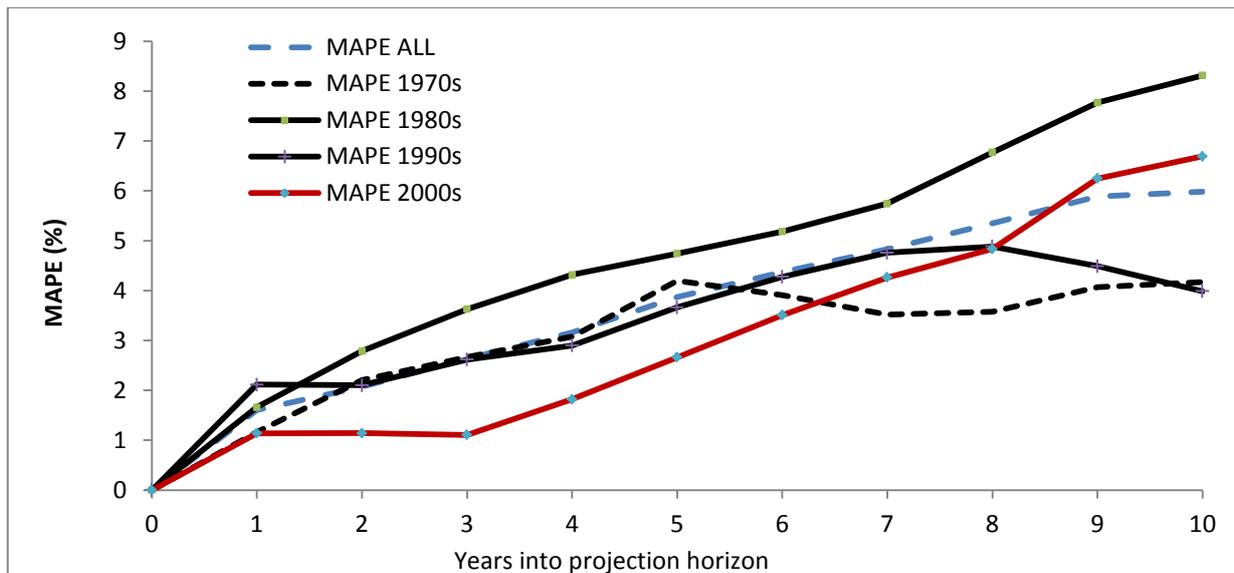
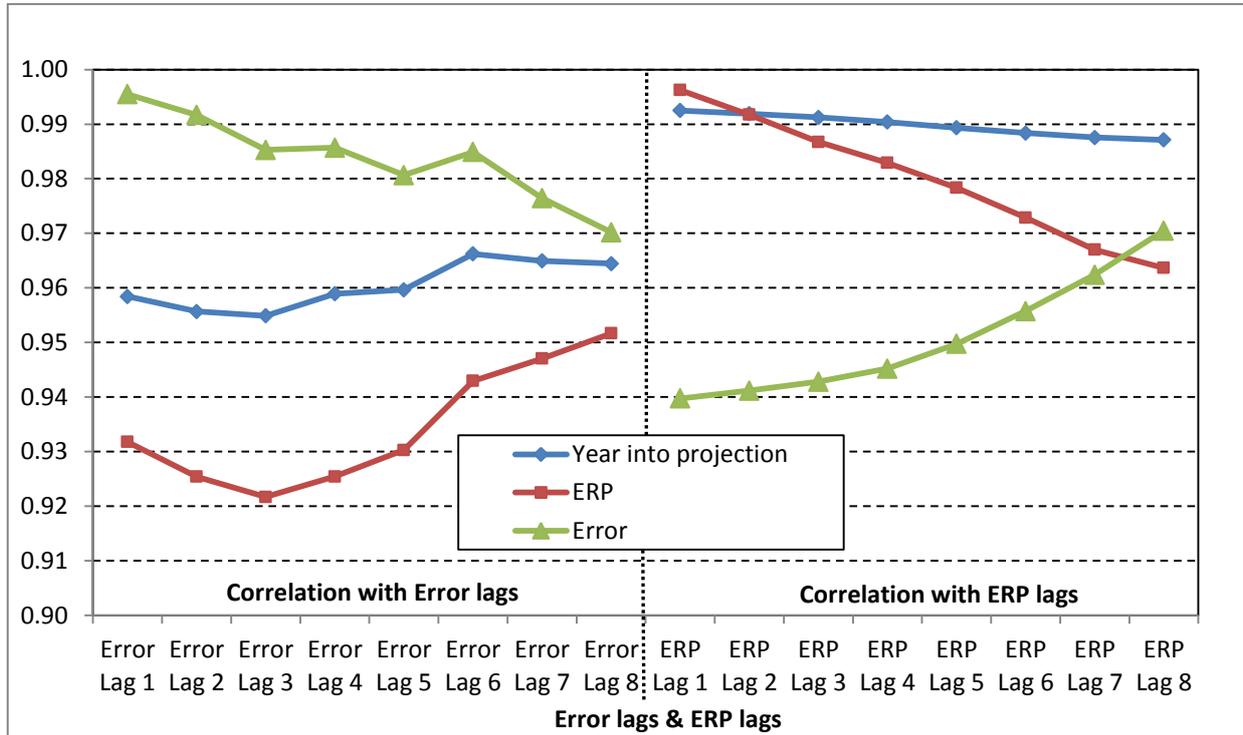


Figure 5. First ten years MAPE for individual decades of ABS projections (all series)



Results from the temporal autocorrelation analysis suggest there may be evidence of instability in the Estimated Resident Population (ERP) figure for the NT (Figure 6). Specifically, this is seen in the ‘u’ shaped (red) series showing the temporal correlation of ERP to the Mean Absolute Percentage Error (MAPE) level. The correlations suggest temporal autocorrelation is variable according to the autocorrelation lag which is applied.

Figure 6. Correlation coefficients for Estimated Resident Population (ERP) and error lags



4.4 Comparison of NT projections accuracy from alternative sources

The evaluation of ABS projections is now compared to alternative sources, including a simplified (naïve) model, NTPOP and the Australian Department of Health and Ageing projections. Figure 7 shows there are significantly lower errors associated with naïve projections in comparison to the Australian Bureau of Statistics (ABS) MAPE. Unlike the ABS forecasts, for example, there is only a relatively small increase in the naïve model MAPE after ten years into the forecast and the 20 year MAPE is not substantially higher than the very early years of the forecast. Meanwhile the NTPOP and Health and Ageing projections track at relatively low error rates during the initial seven years.

Figure 7. Comparing Mean Absolute Percentage Error (MAPE) errors for ABS (middle series) with naïve and other models

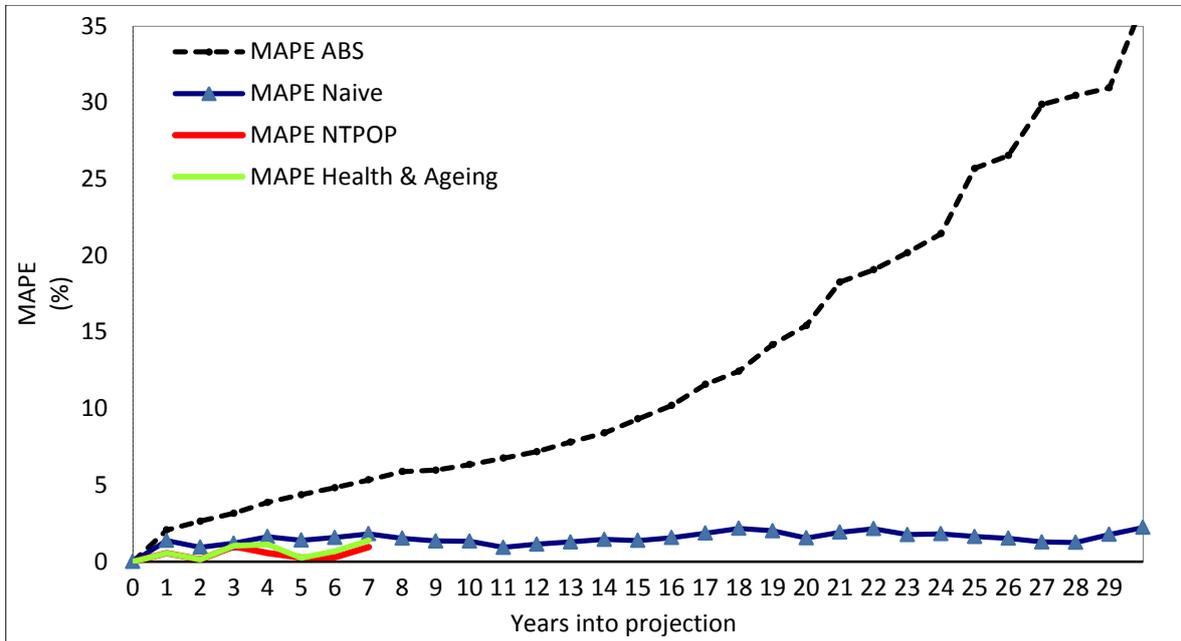
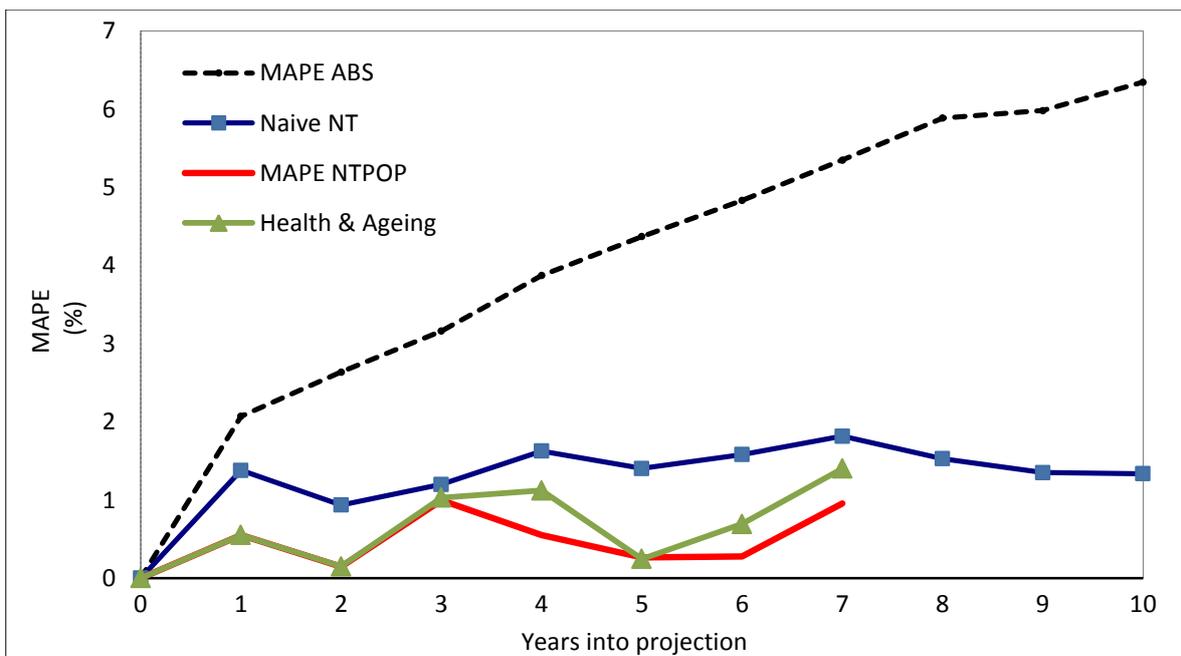


Figure 8 shows the first ten years of MAPEs for ABS alternative projections. Both the NTPOP and the Australian Department of Health and Ageing models exhibit relatively low errors, even when compared to the naïve projection. Encouragingly, the NTPOP model appears to be quite accurate, or at least is not subject to the upward trajectory of the ABS MAPE.

Figure 8. Comparisons of MAPE accuracy by sources, first ten years



5. Discussion

In light of the demographic characteristics and demands for population projections for sparsely populated areas (SPAs) in developed nations, this study sought to assess the accuracy of population projections made for the Northern Territory. Several measures of accuracy were applied to ABS projections and these were compared and contrasted to projections from other sources. The research questions included:

- How accurate have ABS projections for the NT been in comparison to Australia?
- Is there bias in the errors towards underestimation or overestimation?
- Has the relative accuracy of projections for the NT improved over time?
- Would a simplified projections technique (a naïve model) or projections from other sources produce more accurate results?
- What might the answers to these questions tell us about developing better projections for SPAs more broadly?

The analysis shows high errors for NT ABS projections compared to Australia occurring across the lifespan of projections. In line with international findings on projection errors, the magnitude of error for the NT increases during the progression into the forecast years, such that the MAPE error increases substantially after only a few years. In terms of bias, the middle series of ABS projections over four decades show a significant over-estimation of the eventual NT population in projections modelled up to the 1989 edition when the NT population was under-projected right up to the most current ABS release for 2006 (with the exclusion of the 1997 middle series). In general, just 20 years into the projections, the magnitude of over estimation for the total NT population was around a quarter of the eventual population.

Inter-decade comparisons of errors delivered mixed results about whether projections accuracies are improving. MAPE and MPE errors for projections based in the 1990s were relatively low by historical comparison for the NT but indications for 2000s based projections are of a return to higher error rates. This raises the question of whether and to what extent temporal instability in the Estimated Resident Population (and perhaps specifically for the 1990s) might exist as an influence on inter-decade shifts in accuracy rates? Part of the issue may lie in changing methods over time upon which the ABS bases its calculations of the Estimated Resident Population (ERP), although these are generally accounted for by back casting of the ERP according to the current method and through the release of historical records of ERPs. Empirical testing of temporal autocorrelations between the ERP and error levels conducted in this study suggest there may be indeed some temporal ERP instability such that, even if improvements in error rates had occurred over successive decades, this may not, in the case of the NT, indicate systematic improvements in projections. While such instability may be smoothed-out in large population estimates, in small populations this underscores the issues of applying demographic techniques focused on accurate national and supra-national population estimation and projections processes. Equally, this supports the development of alternative approaches to projections for SPAs are defensible and

provides a forewarning to users of projections for SPAs about acceptance of projections from national statistical organisations.

The extrapolation of growth rates using a naïve projections method produced much lower errors across all years of forecasts and for all base years. The relatively low MAPE for the alternative models (NTPOP and Health and Ageing), and particularly for the NTPOP model, are encouraging, although the measure of MAPE is comprised from just a few data points (seven years into the projections). Consequently, this study confirms ABS population projections for the NT have been subject to significantly higher errors than for Australia and other forms of modelling would have provided more accurate numbers. Nevertheless, the aim is not to lambast the ABS who, despite persistent budget cutbacks in recent decades, maintains their national statistical agency role with dedication, expertise and professionalism. Rather, the results here demonstrate SPAs inevitably will face higher levels of errors in projections with this study being the first to document the scale and changing directions of these.

Meanwhile the scale and changing direction of PEs demonstrates one of the fundamental weaknesses of deterministic projections, such as the cohort component model, in the context of SPAs. These essentially apply averages from several years of historical data (for example, averages of net interstate migration) as the basis for assumptions on future directions for each component of change. Hence, projections compiled during periods of population decline, stagnation or low growth have tended to under estimate future population numbers while the reverse is the case for projections compiled during periods of relatively high growth. Projections for the NT made during the early 1980s are a prime example, inherently assuming very high rates of population growth experienced in the late 1970s would continue, while the actual growth rate plummeted during the 1980s. This is consistent with international literature on projections showing that errors are closely associated with population trends in the base years. It is feasible that the population size of SPA jurisdictions, like the NT, can reach a point where swings in the parameters for projections as well as temporal variations in the ERP are smoothed out through scaled effects, although assessing when this might occur is not a simple task.

6. Conclusion

Results in this study provide a sense of the issues confronting the ABS and others in delivering accurate assessments on the size and composition of the Territory's population and consequently in 'doing' projections for SPAs. Such challenges are by no means unique to Australia, with national statistical organisations in Canada, Alaska and the Nordic Circle facing the same issues. This study's findings also challenge policy makers, demographers, planners and users of population information in SPAs across the globe to work collaboratively in trying and testing alternative methods for projections. NTPOP is a prime example insofar as, although it is a cohort component model like those of the ABS, it separately projects Indigenous and non-Indigenous people and allows for demographic interactions to occur between these cohorts. There are other modelling methods that are gaining traction. In the NT, a project has just commenced which is examining the capacity for agent based modelling to shed light on the demographic futures of small settlements

(Taylor et al., 2012). Microsimulation is being used by Statistics Canada for projections of remote area populations, and Wilson and others have done much work on probabilistic projections as an alternative to cohort component modelling (for example, Wilson and Rees, 2005).

The inaccuracy of complex projections, into which a lot of work and money are invested, might suggest that these are not worthwhile or that somehow the whole exercise is fundamentally flawed. Instead, it must be recognised that the ABS works in conjunction with State and Territory governments and the research community to perennially improve projections which by necessity are derived in a hierarchical process from the national level down. Nevertheless, in spite of these efforts, there is no clear evidence from the research in this study to indicate systematic improvements in the accuracy of projections for the NT over time.

In light of this study, the advice to users of population projections for sparsely populated areas is to not take the projected numbers as given or at face value. Instead it is important that user communities work with the custodians of projections and invest time into developing an understanding of the assumptions behind the numbers to build knowledge about their limitations and fit-for-purpose. In turn, remote communities should be actively engaged in helping to identify, from their perspective, the factors likely to influence demographic change into the future. Too often demographers work within the confines of codified data sets and focus on intricacies and shapes for statistically generated curves as likely representations of reality. Given the results here, there is clearly room for considering whether and how information ‘from within’ might be incorporated into the development of projections for SPAs. Hence, while the study of errors in projections is an endorsement of the inestimable benefits of hindsight, it is also a reminder that population projections for SPAs areas must not be taken as predictions. Their real value lies in the role which they can play in stimulating knowledge, improving the range and quality of data stocks and in generating dialogue and networks, all of which are likely to deliver long term improvements in the accuracy of the projections themselves.

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