Population Projections by Age for Florida and its Counties: Assessing Accuracy and the Impact of Adjustments

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ABSTRACT

Projections of total population have been evaluated extensively, but few studies have investigated the performance of projections by age. Of those that did, most focused on projections for countries or other large areas. In this article, we evaluate projections by age for Florida and its counties, as produced and published between 1996 and 2010 by the Bureau of Economic and Business Research (BEBR) at the University of Florida. We first compare the precision and bias of projections of total population with the precision and bias of projections by age, at both the state and county levels. This is followed by a more detailed examination of county-level projection errors for individual age groups, first in the aggregate and then disaggregated by sex and population size. The second part of the analysis focuses on a number of adjustments that were implemented in projections published in 2006 and 2009. Intended to improve accuracy, these adjustments involved updates to the base population, fertility rates, and survival rates. We compare the accuracy of projections incorporating these adjustments with the accuracy of projections excluding them. We believe this study offers a unique opportunity to examine a variety of characteristics regarding the forecast accuracy of small-area population projections by age.

KEYWORDS

Population projections; forecast accuracy; forecast bias; age; symptomatic indicators; adjustments.

Introduction

Population projections by age are critical for many types of planning, budgeting, and policy decision making. For example, planning for public education requires projections of the school-age population; planning for obstetrical services requires projections of the female population of childbearing age; and planning for long-term nursing home care requires projections of the older population. Applications in which age has played in important role include projections of school enrollment (Carey 2011; Hansen 2010; Sweeney and Middleton 2005), crime rates and prison populations (Blumstein, Cohen, and Miller 1980; Jiang and Sánchez Barricarte 2011), child care (Harding, Vidyattama, and Tanton 2011), hospital and long-term care (Chung et al. 2009; Costa-Font et al. 2008; Schofield and Earnest 2006), and many disease and health-related issues (Nowatzki, Moller, and Demers 2011; Greinacher et al. 2011). Age is also an important ingredient in employment and labor force projections (Fullerton Jr. 2003; Wyatt 2010) and in projections addressing regional infrastructure planning (Kronenberg and Moeller-Uehlken 2008), public spending and government budgeting (Kluge 2012; Lee, Tuljapurkar, and Edwards 2010), and economic growth (Bloom et al. 2007; de la Croix, Lindh, and Malmberg 2009).

In spite of its importance, relatively few studies have examined the accuracy of projections by age. Just how accurate are age-group projections? Can some age groups be projected more accurately than others? Do certain patterns stand out? Can anything be done to improve forecast accuracy for particular age groups?

In this study, we address these questions by taking a comprehensive look at the accuracy of fifteen sets of age-group projections for counties in Florida. These projections were produced by the Bureau of Economic and Business Research (BEBR) at the University of Florida between 1996 and 2010. In the first part of the analysis, we compare the precision and bias of projections of total population with that of projections by age at both the state and county levels. This is followed by a more detailed examination of county-level projection errors for individual age groups, first in the aggregate and then disaggregated by sex and population size. The second part of the analysis focuses on a number of adjustments that were implemented in the projections published in 2006 and 2009. Intended to improve the accuracy of the projections, these adjustments involved updates to the base population, fertility rates, and survival rates. We investigate the extent to which these adjustments achieved their purposes by improving forecast accuracy.

This study offers a unique opportunity to investigate the impacts of changes in horizon length, the timeliness of the input data, and the incorporation of updated data on population forecast accuracy. Furthermore, whereas most previous studies focused on a limited number of launch years, we investigate changes in forecast accuracy over a fifteen year period. We believe the findings presented in this study will help data producers improve the quality of their projections and will help data users make better-informed decisions when using those projections for decision-making purposes.

Previous Research

Most evaluations of the accuracy of age-group projections have been conducted for large areas such as countries or regions of the world. At the national and regional levels, population changes are primarily driven by fertility and mortality patterns, with international migration playing a relatively minor role in most countries (Bongaarts and Bulatao 2000). Since fertility rates immediately affect only the youngest age group and mortality rates are highest at the oldest ages, one would expect national- and regional-level forecast errors to be highest for those two groups;

in fact, most studies investigating forecast accuracy at the national and regional levels have found support for this pattern.

For the Netherlands, Keilman (1990) reported the lowest levels of accuracy for the youngest and oldest age groups; projections for the former tended to be too high, those for the latter too low. In a review of ex-post errors in historical population forecasts of industrialized countries, Keilman (1997) found a similar pattern of substantially over-projecting younger age groups and under-projecting older age groups. He attributed these findings to the rapid declines in both fertility and mortality rates that forecasters had failed to foresee when making the projections. More recent reviews by Keilman (2007) for various European countries, by Shaw (2007) for the United Kingdom, and by Wilson (2007) for Australia confirmed the generally low levels of precision for projections of these age groups.

For the United States, Guralnik, Yanagishita, and Schneider (1988) examined the accuracy of four series of population projections by age made between 1937 and 1975 for the year 1980. This study focused on the older population and found that at the extreme upper end of the age distribution – those aged 85 and older – projections were the least accurate. Smith and Tayman (2003), in an evaluation of several sets of national population projections made by the U.S. Census Bureau since the 1950s, found the largest errors at the youngest age groups. Errors for the population aged 65 and older were large in some series but not in others; they attributed this finding to the relative stability in mortality trends over the last several decades in the United States. They further concluded that the direction of forecast errors cannot be generalized; rather, it depends on trends in fertility, mortality, and migration.

Large forecast errors for the youngest and oldest age groups are not unique to forecasts made for countries in the developed world. Comparing forecast accuracy from three sets of

United Nations projections for six countries in Southeast Asia, Khan and Lutz (2008) reported the largest errors for the population aged 0–4, followed by those aged 70 and older. This general pattern has also been reported by Bongaarts and Bulatao (2000) for a number of countries and regions of the world.

The error profile of projections for subnational areas is somewhat different than that typically found in national and regional projections. In subnational areas, relatively large errors are often found not only in the youngest and oldest age groups, but also in the young-adult age groups. This finding is generally attributed to the high but volatile migration rates exhibited by young adults. In an evaluation of state-level projections in the United States, Smith and Tayman (2003) found the largest errors for those under age 5 and for 25–34 year olds. The large errors at the youngest ages reflect the difficulty in projecting fertility rates and the large errors for young adults reflect the difficulty of projecting migration rates. The large errors for young adults have lingering effects as the cohort ages, leading to larger errors for older age groups as the projection horizon becomes longer (Smith and Tayman 2003). A recent evaluation of age-group projections for states and territories in Australia revealed similar patterns: errors were relatively large for ages 0–4 and 25–34 and, in some cases, for the very oldest ages as well (Wilson 2012).

Smith and Tayman (2003) also examined the accuracy of age group projections for counties in Florida. They found that errors were generally largest for ages 25–34, 55–64, and 65 and older. Large errors for these age groups were attributed to mobility patterns in Florida: high levels of migration both for young adults and for retirees. In a study of 10-year projections for census tracts in three counties in Florida, Smith and Shahidullah (1995) reported the largest errors for ages 25–34 and 65 and older, while those for ages 45–64 were the smallest.

Large errors for adults aged 20–29 were also found in an evaluation of projections for territorial authority areas in New Zealand (Statistics New Zealand 2008). In addition, errors were relatively large in both the youngest and oldest age groups (0-4 and 85 and older). Overall, the 65 and older population was projected very accurately at the subnational level in New Zealand, which was a function of low migration rates and stable mortality patterns at the older ages in New Zealand.

Not all studies find exactly the same results, but this review of the literature suggests that relatively large errors are often found in the youngest and oldest age groups. Large errors in the youngest group occur because that group is affected not only by uncertainty regarding future fertility rates, but also by uncertainty regarding the future number of women of childbearing age and, in the case of many countries in the developing world, high and unstable rates of infant mortality as well. Large errors in the oldest groups are a bit more difficult to explain, but may be caused by the relatively small populations often found in those age groups and by the more rapid rates of change in mortality rates at older ages than younger ages; age misreporting may also play a role. At the subnational level, large errors are often found for young adults as well. This occurs because migration rates are generally highest for young adults and migration is the most volatile of the three components of population growth at the subnational level; consequently, migration is the most difficult component to forecast accurately at the subnational level. Will similar error patterns be found in Florida?

Terminology and Methodology

Demographers often distinguish between projections and forecasts. A population projection is typically defined as the numerical outcome of a particular set of assumptions regarding future population trends, whereas a forecast is the projection considered most likely to provide an accurate prediction of the future population (Smith, Tayman, and Swanson 2013). In this analysis, we treat projections as if they were meant to be used as forecasts of the future population and evaluate accuracy by comparing projected numbers for 2000 and 2010 with the numbers counted in the 2000 and 2010 censuses. We use the following terminology:

1) Base year: the year of the earliest data used to make a projection.
2) Launch year: the year of the most recent data used to make a projection; for the projections examined here, the launch year is the year immediately preceding the publication year.
3) Target year: the year for which the population is projected.
4) Base period: the interval between the base year and launch year.
5) Projection horizon: the interval between the launch year and target year.

For example, if data from 1990 through 2000 were used to project the population in 2010, then 1990 would be the base year; 2000, the launch year; 2010, the target year; 1990–2000, the base period; and 2000–2010, the projection horizon.

BEBR has been producing population projections by age and sex for Florida and its counties since the mid-1980s. In this study, we evaluate the accuracy of fifteen sets of projections with launch years from 1995 to 2009 for target year 2010 by comparing them with counts from the 2010 census. We start with 1995 because it was the earliest data set available in electronic form (for a detailed description of the methodology used in the most recent set of projections evaluated in this study, see Smith and Rayer 2010). For comparison purposes, we also analyze forecast accuracy for target year 2000 for the five sets of projections with launch years between 1995 and 1999.

The county projections were produced using a two-step process. First, projections of total population were made using several trend extrapolation methods (linear, exponential, shift-share, share-of-growth) based on several different base periods (five, ten, and fifteen years). The final projection for each county was a trimmed mean of the individual projections and was controlled to an independent projection of the state population, produced using a cohort-component model. Second, for all launch years except 2003, projections by age and sex were made using a cohort-component model in which births, deaths, in-migration, and out-migration were projected separately for each age/sex cohort in the population; these were controlled to the county projections of total population described in the first step. Except for the 2003 projections, all sets analyzed in this study used an essentially unchanged set of assumptions, though new input data were incorporated over time. A more detailed description of the methodology can be found in Smith and Rayer (2004, 2006, 2009, and 2010).

The 2003 set of age and sex projections was made using the Hamilton-Perry method, a simplified version of the cohort-component model (Smith and Rayer 2004). The Hamilton-Perry method is based on cohort-change ratios that combine two components of population change, mortality and net migration (Hamilton and Perry 1962). It was used for the 2003 set of projections because the more detailed migration data required by a cohort-component model were not yet available from the 2000 census. When they became available later that year, they were used in the 2004 projections (projections with launch years between 1995 and 2002 used migration data from the 1990 census).

For total population and each age group, forecast errors are presented as percent errors and are calculated as follows:

$$PE_t = [(F_t - A_t) \div A_t] \times 100,$$

where PE is the percent error, t the target year, F the population forecast, and A the actual population (represented here as counts from the 2000 and 2010 censuses). We use two measures of forecast accuracy, the mean absolute percent error (MAPE) and the mean algebraic percent error (MALPE):

$$\text{MAPE} = \sum |PE_t| \div n$$

$$\text{MALPE} = \sum PE_t \div n,$$

where n equals the number of areas. The MAPE represents the average percent difference between forecasts and actual populations, ignoring the direction of error. It is a measure of precision, or how close projections were to census counts, regardless of whether they were too high or too low; larger MAPEs reflect lower precision. The MALPE is a measure in which positive and negative values offset each other; it is used to indicate bias. A positive MALPE reflects a tendency for projections to be too high while a negative MALPE reflects a tendency for projections to be too low. Both the MAPE and the MALPE have been used extensively to measure the forecast accuracy of population projections (Keilman 1990; Smith and Sincich 1992; Wilson 2012). Refinements to these measures – such as those using weights or a rescaled MAPE-R – have been proposed, but it is not clear whether for practical purposes these more complex measures offer more information than the easier-to-understand MAPE and MALPE (Rayer 2007; Swanson, Tayman, and Bryan 2011; Tayman, Swanson, and Barr 1999).

Projections were made for males and females in five-year age groups from ages 0–4 through 80–84, plus an open-ended group for persons aged 85 and older. To facilitate the discussion of results, we grouped data into eight age categories: 0–4, 5–19, 20–29, 30–44, 45–59, 60–74, 75–84, and 85 years and older. Because previous studies have often found elevated errors for the youngest and oldest age groups, we present results for ages 0–4 and 85 and older separately. For all other ages, we combined two or three five-year age groups into larger intervals of ten or fifteen years. The categories were chosen according to the error profiles of the individual five-year age projections; that is, we combined two or three adjacent five-year age groups when their MAPEs and MALPEs were similar. For the six age categories exceeding five years, the MAPEs and MALPEs shown in Figures 3–6 and Table 1 represent the average MAPE/MALPE of the individual five-year age group projections within each broader age category.

To set the stage for the empirical analysis, we note that Florida is a unique state in several ways. It is the fourth largest state in the United States and has been one of the most rapidly growing states for many decades. It receives a large number of in-migrants, both from other states and from abroad. Net migration typically accounts for 80–90 percent of the state's population growth and – although births outnumber deaths for the state as a whole – approximately one-third of the state's counties have more deaths than births. Its proportions black, Hispanic, and foreign born rank in the top ten nationally. It has the highest proportion aged 65 and older of any state, and one of the lowest proportions aged 15 and younger. These characteristics differ substantially from one county to another, creating a great deal of demographic diversity within the state and providing a rich data set for evaluating the accuracy of population projections by age.

It should be noted that Florida's annual population growth rates are strongly affected by changing economic conditions. During the past decade, for example, growth topped 400,000 in 2004–2005 but fell rapidly during the ensuing recession, dropping below 100,000 in 2008–2009. These dramatic changes added to the difficulty in producing accurate population projections in recent years

Results

a. State and County Projections

We begin our analysis by examining the forecast accuracy of all state and county projections for target year 2010 released between 1996 and 2010. Based on prior research, we expect the projections to become more precise with decreasing horizon length. We also expect the incorporation of new census data to reduce forecast errors. On the other hand, the longer one uses input data from a previous census, the more out-of-date those data become, potentially leading to larger errors later in the decade; this may counteract the often-found inverse relationship between horizon length and precision.

(Figure 1 about here.)

Figure 1 displays two data series for both state and county projections: one showing MAPEs for total population and one showing MAPEs by age averaged over all age categories. Echoing the findings by Smith and Tayman (2003), for all launch years at both the state and county levels, the projections were more precise for total population than for age groups. For launch years prior to 2004, both series of state projections were more precise than both series of county projections. Starting in 2004, the county projections of total population were slightly more precise than the state projections for age groups, and even approached the precision of the state projections of total population in 2005 and 2006.

For all projection series, MAPEs showed relatively little change from year to year between 1995 and 1999 but declined substantially between 1999 and 2000. The reason for this sudden improvement in accuracy was that the 1999 projections were based on post-censal population estimates whereas the 2000 projections were based on census counts; given that census counts are generally more accurate than estimates, projections based on counts are generally more accurate than projections based on estimates (other things being equal). MAPEs followed an up-and-down pattern between 2000 and 2010, first rising and then falling. The large errors between 2003 and 2006 were caused primarily by high rates of population growth during the middle of the decade followed by a tremendous slowdown caused by the recession of 2007–2009. Projections of total population showed steady (albeit modest) improvements in precision between 2006 and 2009, primarily because the projection horizon was becoming shorter. Projections of age groups, however, did not become more precise after 2007.

To put these numbers in perspective, Smith, Tayman, and Swanson (2013) reported “typical” MAPEs of 3, 6, and 9 percent for state-level projections of total population covering five, ten, and fifteen year projection horizons, respectively. For county-level projections of total population, typical MAPEs were 6, 12, and 18 percent, respectively. In evaluating several sets of state-level projections, Smith and Tayman (2003) found MAPEs to be 10–30 percent larger for age-group projections than for projections of total population. For county-level projections, MAPEs for age-group projections were 40–60 percent larger than MAPEs for projections of the total population.

(Figure 2 about here.)

Figure 2 is structured analogously to Figure 1 but focuses on bias. In contrast to the results for precision, MALPEs did not differ nearly as much from one series to another, especially from 2000 to 2007, when all four series tracked each other closely. For both the state and county projections, MALPEs for total population were lower than the ones by age; that is, the projections of total population had more downward bias than the age group projections when MALPEs were negative and less upward bias when MALPEs were positive.

Figure 2 also illustrates the sensitivity of the projections to the incorporation of 2000 census counts and to recent changes in rates of population growth. Three of the four series had negative MALPEs for launch years prior to 1999. This occurred because the population estimates made during the 1990s turned out to be a bit low, causing the 2010 projections to be a bit low as well. Florida experienced very high population growth rates between 2003 and 2006, followed by very low rates between 2007 and 2010. This caused the projections made in the middle of the decade to be substantially too high. MALPEs declined considerably in the latter part of the decade and the 2009 projections – the last projection before results from the 2010 census became available – had very low levels of bias for three of the four series, the only exception being the county projections by age.

b. County Projections by Age

Figure 3 provides a more detailed look at the precision of the age-group projections. MAPEs were by far the largest for the oldest age group (85+) in every launch year and were relatively large for the next oldest age group as well (75–84). They were relatively large for the 20–29 and 30–44 age groups for launch years in the 1990s and for the 20–29 age group for launch years in the 2000s. They were relatively small for the 45–59 and 60–74 age groups for all launch years. These results are largely in accordance with findings from previous research, although we did not find the elevated MAPEs for ages 55–64 for Florida counties reported by Smith and Tayman (2003).

(Figure 3 about here.)

The aggregate data displayed in Figure 1 suggested that – apart from the incorporation of new census data in 2000 – there was essentially no improvement in precision for the projections over time. The more detailed data shown in Figure 3 reveal a more nuanced pattern. From 1995 to 1999, while MAPEs for projections of total population decreased slightly, MAPEs for several age groups increased slightly (for age 85+, they increased substantially). The projections for launch year 2000 were much more precise than in previous years, reflecting the incorporation of data from the 2000 census. There was some improvement in precision throughout the 2000s – several age groups had MAPEs that declined between 2000 and 2009 – but the average age-group error dropped only from 11.2 in 2000 to 10.0 in 2009 (not shown here). This was because MAPEs for ages 20–29 and 85+ increased throughout the decade, offsetting the improvements in the other age groups.

Also noteworthy is the somewhat unusual error profile of the projections with launch year 2003. This set stands out by exhibiting relatively small MAPEs for all age groups and the smallest MAPEs of any launch year for the two oldest groups. The most likely cause of this unique error profile is the methodology used for that set of projections. A cohort-component model – in which births, deaths, and in-and out-migration are projected separately for each age-sex cohort – was used in all launch years except 2003. In 2003, the simpler Hamilton-Perry method – in which the effects of mortality and net migration are combined in a single factor – was used.

In previous research, the Hamilton-Perry method has been found to produce age-group projections for small areas that are as accurate as those produced using more complex models (Smith and Tayman 2003). Although the limited results presented here are insufficient to fully evaluate the accuracy of these two types of models, the good performance of the 2003 set is intriguing.

(Figure 4 about here.)

Figure 4 is structured analogously to Figure 3, but focuses on bias rather than precision. This figure shows that the projections of total population for target year 2010 had a small negative bias for most launch years prior to 2003 and a small positive bias thereafter. MALPEs for age groups 5–19, 30–44, 45–59, and 60–74 were also generally negative for launch years prior to 2003 and positive thereafter, whereas projections for the two oldest age groups had positive MALPEs in every launch year; projections for age groups 0–4 and 20–29 had a positive bias in all launch years except 1995 (ages 20–29) and 1996 (ages 0–4). The upward bias was particularly strong for the oldest age group (85+), and it increased throughout each decade.

Our analysis thus far has focused on comparisons to 2010 census counts. The projections with launch years 1995 to 1999 can also be compared to 2000 census counts; this allows us to determine whether the patterns shown in Figures 3 and 4 were unique to target year 2010 or can perhaps be generalized. Figures 5a, 5b, 6a, and 6b show MAPEs and MALPEs for the five sets of projections published immediately preceding the 2000 and 2010 censuses (i.e., launch years 1995–1999 for target year 2000 and launch years 2005–2009 for target year 2010).

(Figures 5a and 5b about here.)

For total population, MAPEs for 2000 changed very little as the launch year approached the target year (Figure 5a); for 2010, they declined slightly as the launch year approached the target year (Figure 5b). For individual age groups, errors sometimes declined and sometimes increased as the launch year approached the target year; these changes were generally very small. These results suggest that errors in the age estimates for the launch years contributed significantly to errors in the projections themselves, canceling out the beneficial effects of a shorter projection horizon. We expect that for longer horizons (e.g., 20–30 years), errors would become noticeably smaller as the launch year approached the target year. With the exception of the oldest group (85+), errors for individual age groups were fairly similar in both sets of projections. The general patterns were about the same, with the largest errors in the 20–29, 75–84, and 85+ age groups and the smallest errors in the 5–19, 45–59, and 60–74 age groups.

(Figures 6a and 6b about here.)

Figures 6a and 6b provide the corresponding results for bias. For target year 2000, MALPEs for total population turned from slightly negative in 1995 to slightly positive in 1999; for target year 2010, projections were too high in each launch year but the upward bias declined as the decade progressed. For individual age groups, MALPEs generally went up with the launch year for target year 2000 – reflecting increasing bias for age groups with positive MALPEs and decreasing bias for age groups with negative MALPEs – and went down for target year 2010 for all age groups but 85+. Age groups 0–4, 20–29, 75–84, and 85+ had positive MALPEs for every launch year in both sets of projections; in most instances, the absolute values of those MALPEs were larger than for any other age group. Projections for age group 60–74 displayed a slight negative bias for every launch year, while those for age groups 5–19 and 30–44 had a slight negative bias for target year 2000 and a slight positive bias for target year 2010. We don't believe we can draw general conclusions regarding the bias of age-group projections, other than to note that bias (in either direction) is likely to be smallest for the age groups where precision is greatest.

To summarize, the BEBR county projections by age for target years 2000 and 2010 were generally similar in terms of their error profiles, especially with respect to precision. Age groups with the largest MAPEs in 2010 (20–29, 75–84, and 85+) also had the largest in 2000, while age groups with the smallest MAPEs in 2010 also had the smallest in 2000. The relatively large errors found for young adults and the oldest age groups are consistent with previous research.

Results for MALPEs were not as consistent, confirming the generally unpredictable nature regarding the direction of forecast errors.

c. County Projections by Age and Sex

Although population projections often provide breakdowns into males and females, few studies have evaluated their respective accuracy. Yet it may be important to know whether there are differences in the precision and bias of age-group projections for males and females because age- and sex-specific projections are essential for many purposes (e.g., projecting fertility rates, labor force participation rates, crime rates, and various health conditions). Smith and Tayman (2003) found errors for males and females to be similar within each age group for state and national projections. For counties in Florida, they found errors to be somewhat larger for males than for females, especially at younger ages, although females had slightly larger errors for ages 65 and older. Shaw (2007) reported the opposite for the United Kingdom: larger errors for males at most of the older ages and larger errors for females at young adult ages. Wilson (2007) found generally similar MAPEs for age-sex-specific population forecasts for Australia, with errors for males exceeding those for females at older ages. Evaluating national-level forecast errors by age and sex, Keilman and Kucera (1991) reported larger errors for females at older ages for the Netherlands while for Czechoslovakia it was the other way around. From the limited number of analyses done so far it appears that, in contrast to the relatively predictable forecast error patterns observed by age, error patterns by sex are not as consistent.

To investigate whether there were any differences in forecast accuracy by sex, we replicated the analyses shown in Figures 3–6 separately for males and females. Overall, we found little evidence of differences in precision between the sexes. Errors were similar for males and females, both for the total population and for most individual age groups (not shown here). Results for bias also showed few clear patterns. Although we discovered some unique patterns for individual age groups, they did not remain stable over time. Based on these results and those reported in previous studies, we have concluded that forecast accuracy does not vary much between males and females, and where it does, it does so in a largely unpredictable fashion.

d. County Projections by Age and Population Size

Population size has generally been found to have a positive effect on the precision of population projections but no consistent effect on bias (Isserman 1977; Rayer 2008; Smith and Shahidullah 1995; Smith and Sincich 1988; Tayman, Parrott, and Carter 1998). Most studies, however, have focused on projections of total population rather than on projections of specific population subgroups. To investigate whether these relationships hold by age, we compared forecast errors for small and large counties, using a threshold population of 100,000 (roughly the median population size for counties in Florida). To keep the amount of data presented manageable, we calculated errors not for individual launch years but rather for averages of the five sets of projections immediately preceding the 2000 and 2010 censuses; that is, for launch years 1995–1999 and 2005–2009, respectively.

(Tables 1a and 1b about here.)

Table 1a shows that projections for large counties were much more precise than those for small counties. MAPEs for small counties were larger (sometimes much larger) than those for large counties in every age category in both target years. These results are consistent with those reported previously in the literature on the precision of projections of total population. The data also suggest that the large errors for the 20–29, 75–84, and 85+ age groups reported earlier in this study can be attributed in large part to small counties. Although the patterns remain the same, MAPEs do not vary nearly as much from one age group to another in large counties as they do in small counties.

Results for bias (Table 1b) show no systematic relationship between population size and the direction of forecast error. This, too, is consistent with the findings of previous studies.

e. Age-Specific Adjustments

Having investigated the accuracy of fifteen sets of population projections by age for Florida counties, we conclude our analysis by focusing on a number of adjustments that were made in the projections published in 2006. These adjustments were made "to account for the effects of changes on the demographic composition of the population that have occurred since the date of the last census and which the cohort-component projection model may not have picked up otherwise" (Smith and Rayer 2006: 6). We also examine two similar adjustments that were made to the projections published in 2009. These adjustments involved birth data compiled by the Florida Department of Health that were compared to the population aged 0–4; school enrollment data compiled by the Florida Department of Education that were compared to the population aged 5–14; Medicare data compiled by the U.S. Department of Health and Human Services that were compared to the population aged 65 and older; and death data compiled by the Florida Department of Health that were used to create updated life tables, survival rates, and survival rate adjustment factors for the population of all ages.

In order to investigate the impact of these adjustments on the precision and bias of the 2010 projections, we re-calculated the projections published in 2006 and 2009 without making the adjustments that were made originally and compared MAPEs and MALPEs for the adjusted and unadjusted projections. The original adjustments were as follows:

1. The projected population aged 0–4 in 2010 was adjusted by raising or lowering total fertility rates between 5% and 10% in 17 counties in the projections published in 2006 and between 4% and 19% in 23 counties in the projections published in 2009. This was done to reduce the rather large differences between the estimated populations aged 0–4 in 2005 and 2008 and cohort size implied by the birth data for 2000–2004 and 2003–2007, respectively.

2. In the projections published in 2006, the 2000 base year populations in age groups 0–4 and/or 5–9 were raised or lowered by between 5% and 15% in 34 counties. This was done to reduce differences between the estimated populations aged 5–9 and/or 10–14 in 2005 and the available school enrollment data for fall 2004 in grades K–4 and/or 5–9, respectively. This adjustment affected the projections for the populations aged 10–14 and/or 15–19 in 2010.

3. Medicare data generally track the population aged 65 and older quite closely. The projections published in 2006 drew on this relationship to develop an estimate of the population aged 65 and older in 2005 by multiplying the ratio of Medicare enrollees to the population aged 65 and older in the 2000 census by the estimated number of Medicare enrollees in 2005 (based on an extrapolation of the average annual growth rate from 2000 to 2004). In 58 counties, an average between this estimate and the unadjusted 2005 estimate was used to construct the final population estimate of the population aged 65 and older in 2005; because of apparent problems in the Medicare data, the unadjusted cohort-component estimates were used in the nine remaining counties. This adjustment affected the projections of the population aged 70 and older in 2010.

4. The projections published in 2009, in addition to using updated fertility rates for a subset of counties as described above, also incorporated an updated set of survival rates and survival rate adjustment factors, which were applied to all counties. The new survival rates were based on life tables for 2004–2006, which were created using data provided by the Florida Department of Health, and which replaced an earlier series based on life tables for 1999–2001. The survival rates were adjusted upward in 2010 to account for projected increases in life expectancy; these were based on the projected life expectancy for the U.S. population as a whole (Smith and Rayer 2009). To analyze how this adjustment affected forecast accuracy for target year 2010, we compared MAPEs and MALPEs for projections made with the adjusted survival rates and survival rate adjustment factors to those based on unadjusted rates.

Of the four adjustments, only the Medicare adjustment had a measurable impact on forecast accuracy. The other three adjustments were less successful and are summarized briefly below (data tables are available from the authors by request). Adjusting fertility rates had no measureable impact on MAPEs in 2006 but led to modest improvements in 2009. The adjustment led to a small reduction in bias in 2006 but increased bias in 2009. Consequently, while the fertility rate adjustments resulted in more accurate projections for some counties, their overall impact was marginal. The school enrollment adjustments introduced in the 2006 set of projections produced a very modest improvement in precision, but increased bias for both ages 10–14 and 15–19. Thus, as was the case with the fertility rate adjustment, the school enrollment adjustment did not have a measurable impact on overall forecast accuracy. Although there were improvements for some counties, the adjustments reduced accuracy in other counties.

The new survival rates and survival rate adjustment factors introduced in the 2009 set of projections were also only partially successful; the former reduced precision and raised bias, while the latter had the opposite effects. Since mortality rates are quite low for all but the oldest ages, these adjustments had a marginal impact for most age groups. For the two oldest age groups, however, their impact was measurable and, on balance, reduced forecast accuracy. Although one cannot derive definitive conclusions from this limited analysis, these results suggest that using updated input data does not necessarily lead to more accurate projections. In hindsight, it appears that the survival rates calculated at mid-decade underestimated mortality at older ages because of errors in the denominators used in calculating those rates.

(Table 2 about here.)

In contrast to these results, the Medicare adjustments applied in the projections published in 2006 produced a modest but consistent improvement in both precision and bias of projections of the older population. As shown in Table 2, these adjustments reduced MAPEs by 0.7–3.2 percentage points and MALPEs by 2.2–3.2 percentage points. The only exception was males aged 70–74. Although the adjustment reduced the MAPE for this group, it increased the absolute value of the MALPE. Examining results for individual counties confirmed the overall pattern: for ages 70–74, forecast accuracy improved for approximately two-thirds of all counties and for ages 75 and older it improved for more than 90% of all counties (not shown here).

We have already provided several reasons why the survival rate adjustments were largely unsuccessful. Why did the Medicare adjustments generally improve forecast accuracy while the birth and school enrollment adjustments did not? There are two possible explanations. One is that Medicare data are more highly correlated with the older population than birth and school enrollment data are with persons aged 0–4 and 5–14, respectively. As a result, using Medicare data to adjust the projections leads to greater improvements in accuracy than does using birth and school enrollment data. A second explanation is related to the nature of the adjustments. For the vast majority of counties in this data set, adjustments based on Medicare enrollment led to lower projections of the older population. As shown in Table 2, projections for ages 75 and older were much too high in all the years covered by this study. Consequently, the Medicare adjustment was in the right direction in most counties, even though its overall impact on forecast accuracy was modest. The fertility rate adjustment made in 2009 and the school enrollment adjustment made in 2006, on the other hand, generally resulted in higher projections for the relevant age groups. Since the projections for those age groups already had a positive bias, the adjustments often led to even larger errors. The fertility rate adjustment made in 2006 was in the right direction for most counties, but its impact was too small to measurably affect overall forecast accuracy.

Summary and Conclusions

Previous studies have reported a number of common patterns regarding the precision and bias of age-group projections. Although there were some differences by geographic area and time period, national-level projections were generally found to be least accurate for the youngest and oldest age groups while subnational projections often produced relatively large errors for young adults as well. These error patterns reflect the impact of the demographic components of population change – fertility, mortality, and migration – which are of varying importance at different levels of geography. As Smith and Tayman (2003: 754) concluded, "in general, the impact of migration on population change becomes larger as the geographic unit becomes smaller. For any given area, the largest forecast errors are likely to be found in the age groups that are most strongly affected by the major determinants of population change in that area." Although there were certain commonalities in the precision of population projections by age, bias often varied unpredictably by age group and several studies have concluded that the direction of future errors should be considered unknowable at the time a projection is made.

Building on earlier studies, in the first part of this article we analyzed the accuracy of fifteen sets of population projections by age for Florida and its counties, produced and published by BEBR between 1996 and 2010. We found that county projections were generally least accurate for young adults, for the oldest age groups, and in some instances for those aged 0–4 as well. These results are very much in line with the patterns found in previous studies of subnational projections. Difficulties in projecting young adults are largely related to uncertainty regarding their migration patterns. Though not unexpected given the findings of previous research, the low accuracy of the projections for the two oldest age groups (especially the oldest) was surprising in terms of its magnitude. These large errors were most likely caused by the relatively small populations often found in those age groups and by the rapid rates of change in mortality rates at older ages; age misreporting may have played a role as well. In Florida, an additional factor was the high level of retiree migration – including return migration at the oldest ages – found in many counties. Projections for 0–4 year olds showed elevated levels of error primarily for target year 2000; for 2010, errors were no larger than average. For this age group, the primary drivers of low accuracy were difficulties in projecting fertility rates and the number of women of childbearing age.

The analysis of errors by population size indicated that the relatively large errors for the 20–29, 75–84, and 85+ age groups can be attributed primarily to the impact of small population size. Although error patterns by age were similar in both large and small counties, differences among age groups were much greater in small counties.

In general, errors for age groups were larger (sometimes much larger) than errors for the total population. This is not surprising, of course, given that each age group has far fewer members than the total population; in addition, errors in individual age groups may balance each other out in the total population. However, it is notable that the accuracy of the projections of total population evaluated in this study tended to improve as the target year drew closer, whereas the accuracy of age group projections did not always do so. For example, MAPEs for individual age groups averaged 9–11% in every year for projections with launch years between 2000 and 2009 – with only a slight trend toward greater precision by the end of the decade – whereas MAPEs for projections of total population declined from about 5–6% in the early and middle years of the decade to around 3% by 2009 (see Figure 3). As a result, MAPEs for age groups were about twice as large as MAPEs for the total population in the early and middle years of the decade but were about three times larger in the last two years. We believe this pattern occurred because the population projections were based on the most recent estimates available, and post-censal estimates of total population are more reliable than post-censal estimates of age groups. As new census data become available, age group projections for shorter horizons become more accurate as well. This explains why the MAPEs for age groups shown in Figure 3 declined so sharply between 1999 and 2000.

The second part of the article looked at various adjustments and updates to the input data that were introduced in the projections published in 2006 and 2009. Symptomatic indicators are often used to adjust cohort-component projections for small areas, but few (if any) studies have evaluated the impact of such adjustments on forecast accuracy. We found that, with the exception of the adjustment based on Medicare enrollees, such adjustments had little effect on forecast accuracy and occasionally made the projections less accurate. Why did these adjustments not have a greater impact, and why were some of them detrimental? The adjustments based on Medicare enrollment were in the right direction for most counties, but the fertility and school enrollment adjustments often led to higher projections when they were already too high. The 2006 adjustments were applied at a time of high population growth, and the available data on births and school enrollment were suggesting that the BEBR estimates for those age groups may have been too low. While both adjustments lowered the projections for some counties, they raised them in most counties, increasing the extent of the upward bias. Since these adjustments were generally quite modest – raising or lowering rates by only 5% or 10% for most counties – they did not have a big impact on forecast accuracy. Finally, there is also the issue that the various adjustments may have cancelled each other out. The 2006 adjustments for Leon County, for example, raised total fertility rates by 5%, lowered the 2000 base year population aged 5–9 by 5%, and lowered the 2000 base year population aged 60 and older by about 3%. Given that the projections by age and sex were controlled to the county total population projections, it is difficult to foresee the ultimate impact of each individual adjustment.

That some of the adjustments reduced precision and/or raised bias is disappointing, but perhaps not surprising. Calculating an updated set of survival rates based on newly created life tables in mid-decade sounds good in theory, but can be problematic in practice. Since there are no decennial census counts available for 2005, it is impossible to ascertain the extent to which the 2005 BEBR estimates by age and sex were inaccurate; however, it seems likely that they were too high for the older age groups. The population aged 75 and older was estimated statewide at 1,574,546 in 2005, compared to decennial census counts of 1,355,422 in 2000 and 1,531,662 in 2010. Using the 2005 estimates as the basis for calculating a new set of life tables, it is easy to see how the updated survival rates led to lower forecast accuracy. The conclusion we draw from these results is not that one should never use symptomatic indicators or updated input data to adjust population projections, but that the analyst has to carefully weigh the potential gains against the possible costs.

Why does all this matter? Why is it important to evaluate the accuracy of age-group projections? We believe it is important for two reasons. First, it is important because relatively little research has addressed this issue, especially for small areas such as counties. Are age-group projections less accurate than projections of total population? If so, by how much? Can some age groups be projected more accurately than others? Do certain patterns stand out? Can anything be done to improve forecast accuracy for particular age groups? Providing answers to these questions will fill some of the gaps in our understanding of the nature of population projections.

Second, it is important because age-group projections are essential for many types of planning and decision making. Projections of total population are of limited use when assessing future needs for obstetrical services, elementary schools, and nursing home care; when targeting products toward new mothers, first time home buyers, or recent retirees; and when designing daycare, pension, and healthcare programs. All these issues require projections of specific age groups. Sound planning and informed decision making are possible only if data users have an understanding of the potential degree of accuracy of the relevant age-group projections.

This and other studies have found forecast errors to be very large for some age groups (e.g., 85+), even for relatively short projection horizons. This may be disappointing information to data users, but we believe it reflects the reality of small-area age group projections. Does this mean that such projections are of no use for decision-making purposes? That is a question each data user will have to answer individually. We believe having some information is better than having no information at all, but data users must consider potential errors when using population projections. The results presented in this study will help guide such deliberations.

This study answers some of the questions posed above but has several limitations. The data set included counties from only a single state and – although a number of different projection horizons were considered – they were all relatively short. Several of the age groups were fairly broad (e.g., 15 years), and although they were aggregated based on the similarity of their error profiles, some individual variation was undoubtedly missed. The potential impact of factors such as the rate of population growth on forecast accuracy was not evaluated. The effects of controlling the age group projections to independent projections of total population were not evaluated. The number of methods used in constructing the projections – and the variety of assumptions used in applying those methods – was fairly limited. We hope future research will address these issues, adding to the variety of data and techniques that can be used for constructing population projections by age and to our understanding of the accuracy of those projections.

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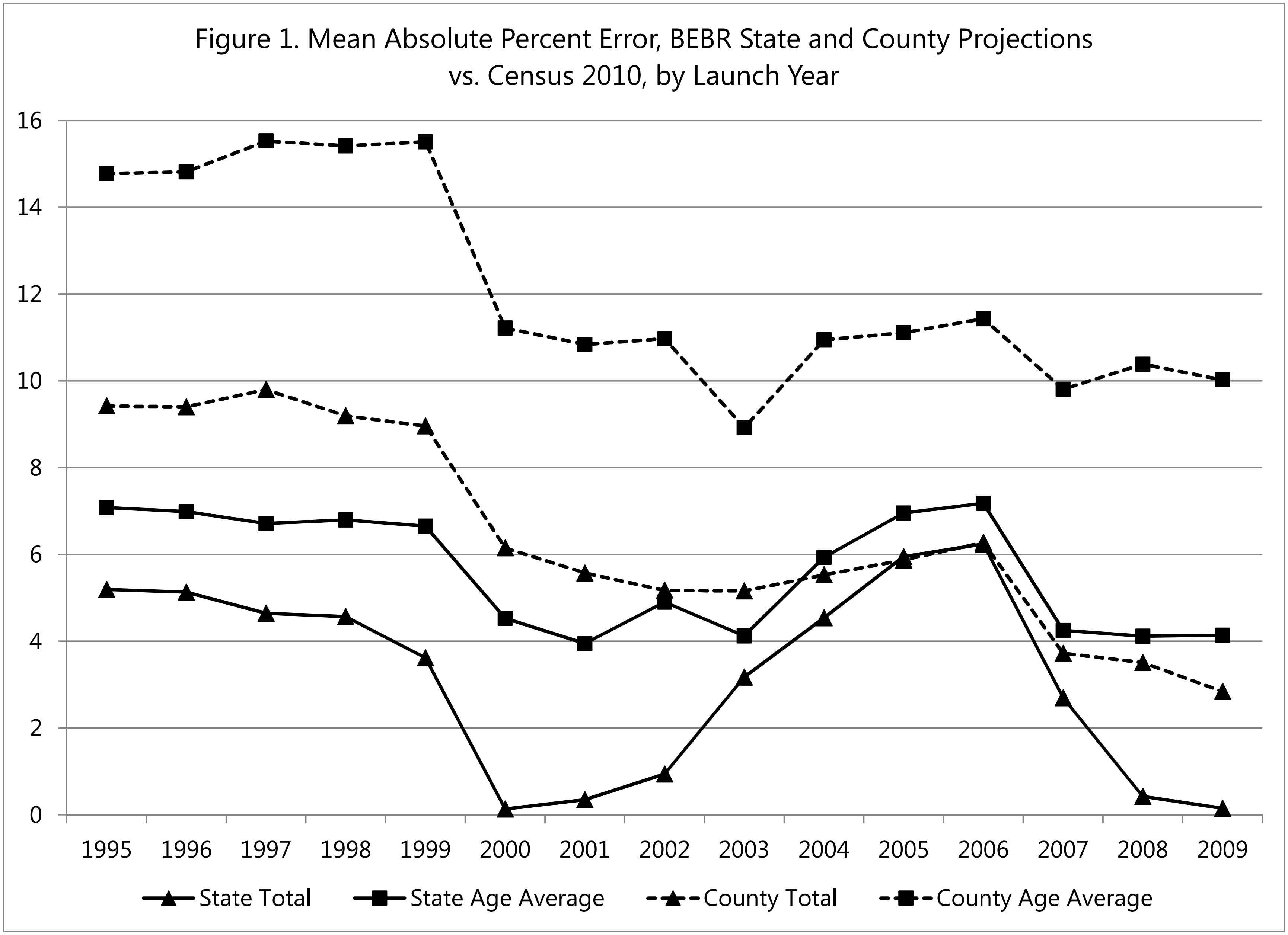
Figure 1. Mean Absolute Percent Error, BEBR State and County Projections
vs. Census 2010, by Launch Year
16
14
12
10
8
6
4
2
0
1995
1996
1997
1998
1999
2000
2001
2002
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2004
2005
2006
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2008
2009
State Total
State Age Average
County Total
County Age Average

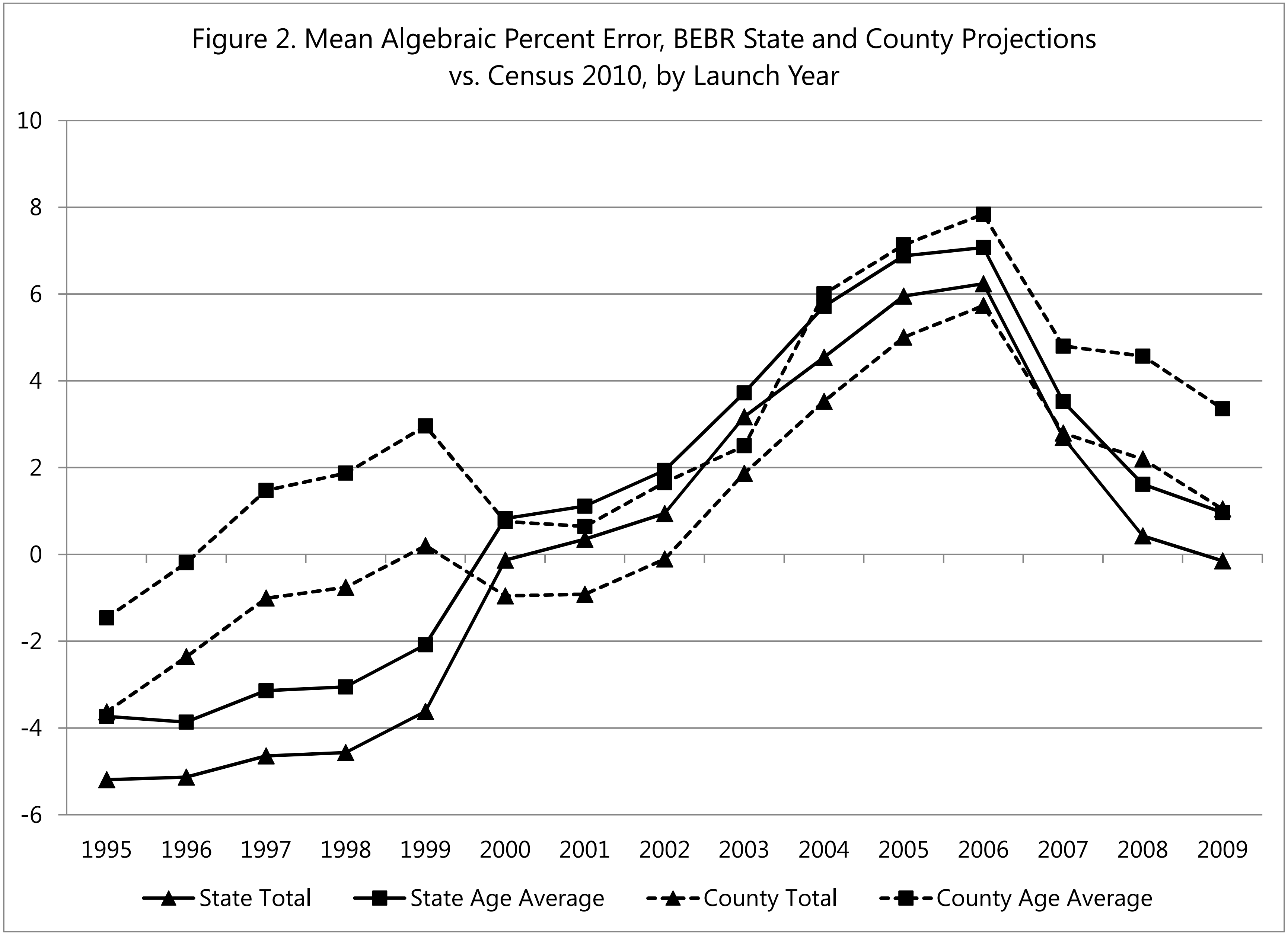

Figure 2. Mean Algebraic Percent Error, BEBR State and County Projections
vs. Census 2010, by Launch Year
10
8
6
4
2
0
-2
-4
-6
1995
1996
1997
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2000
2001
2002
2003
2004
2005
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2008
2009
State Total
State Age Average
County Total
County Age Average

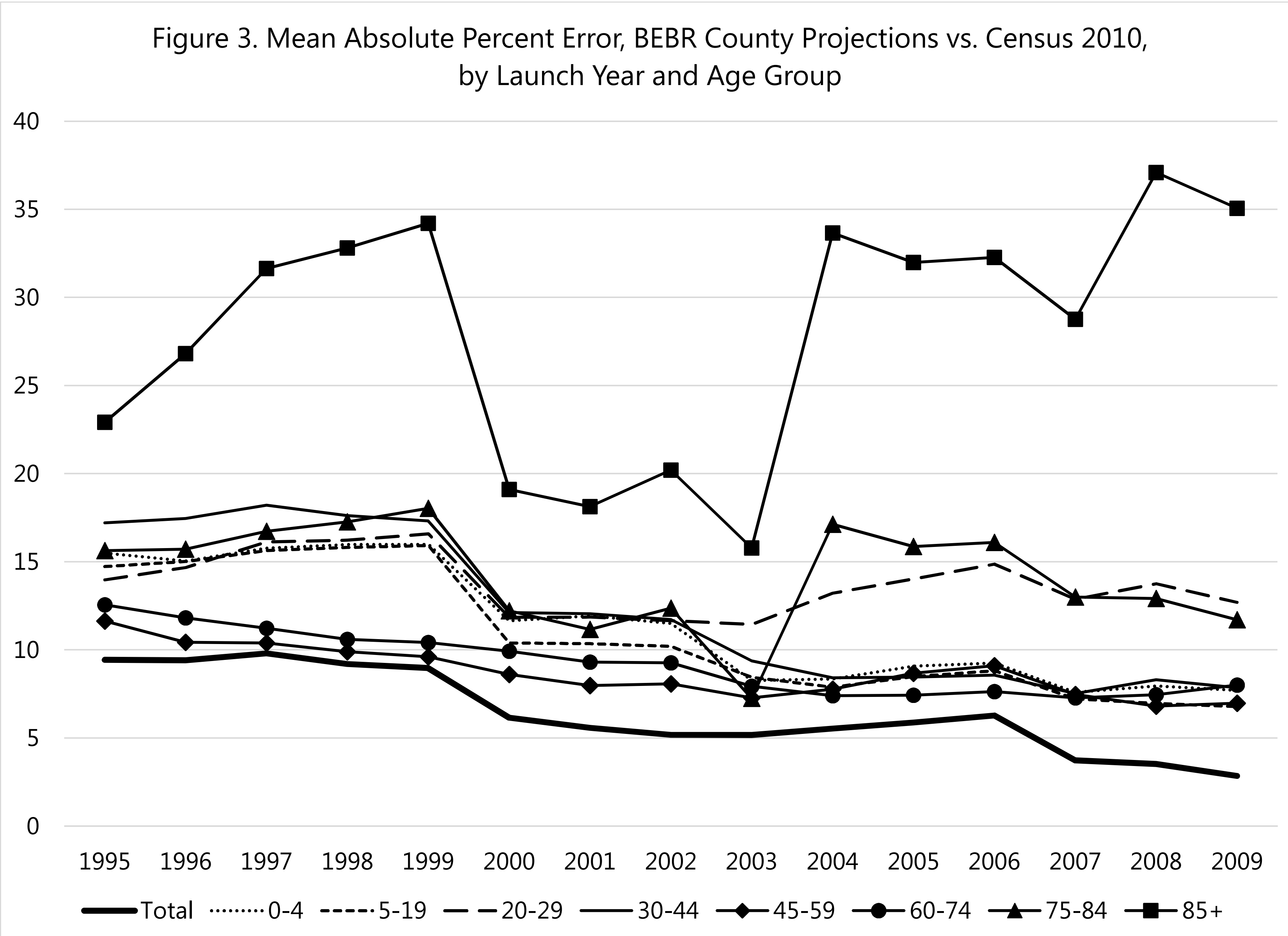


Figure 3. Mean Absolute Percent Error, BEBR County Projections vs. Census 2010,
by Launch Year and Age Group
40
35
30
25
20
15
10
5
0
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Total
0-4
5-19
20-29
30-44
45-59
60-74
75-84
85+

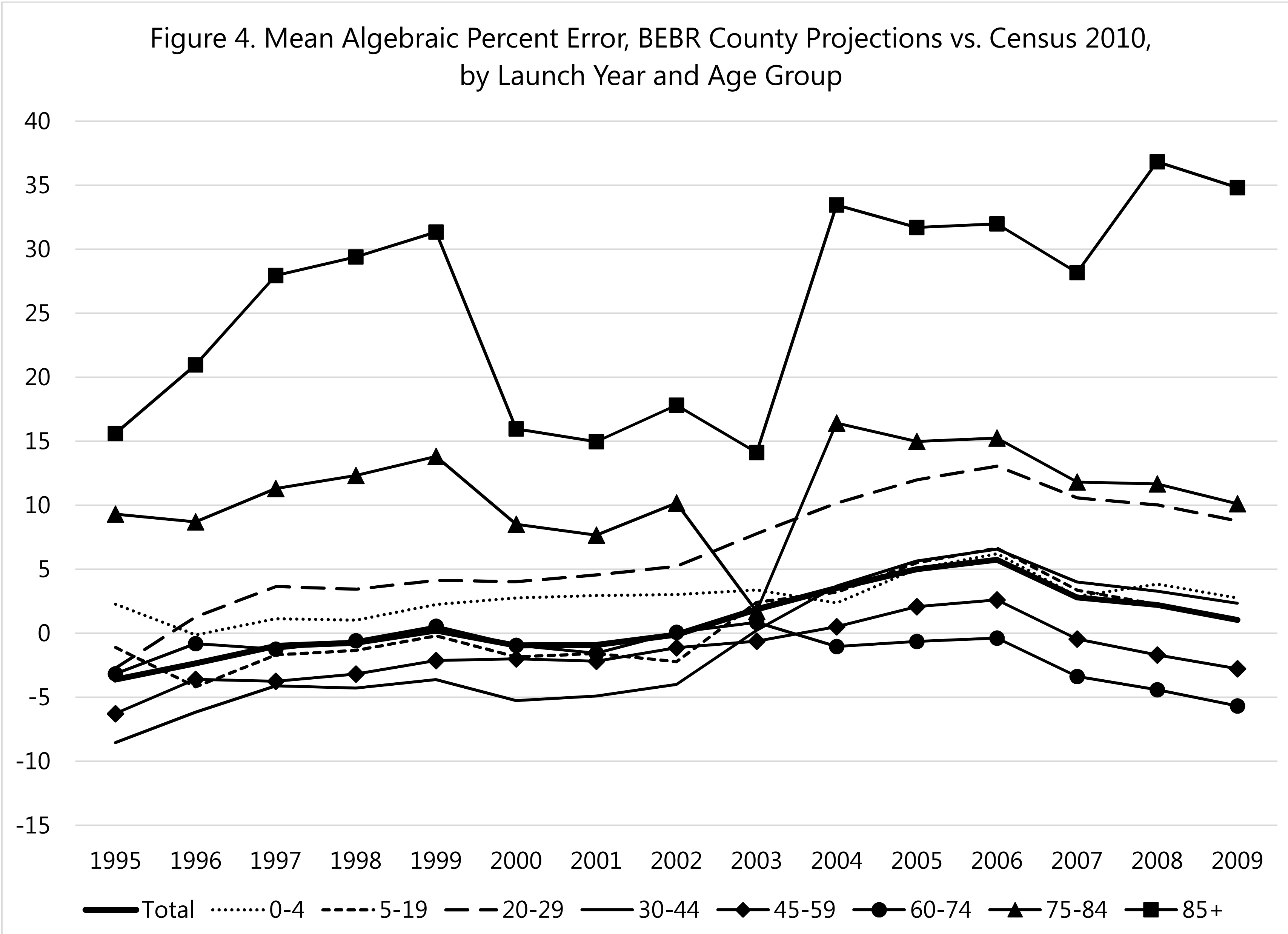


Figure 4. Mean Algebraic Percent Error, BEBR County Projections vs. Census 2010,
by Launch Year and Age Group
40
35
30
25
20
15
10
5
0
-5
-10
-15
1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009
Total
0-4
5-19
20-29
30-44
45-59
60-74
75-84
85+

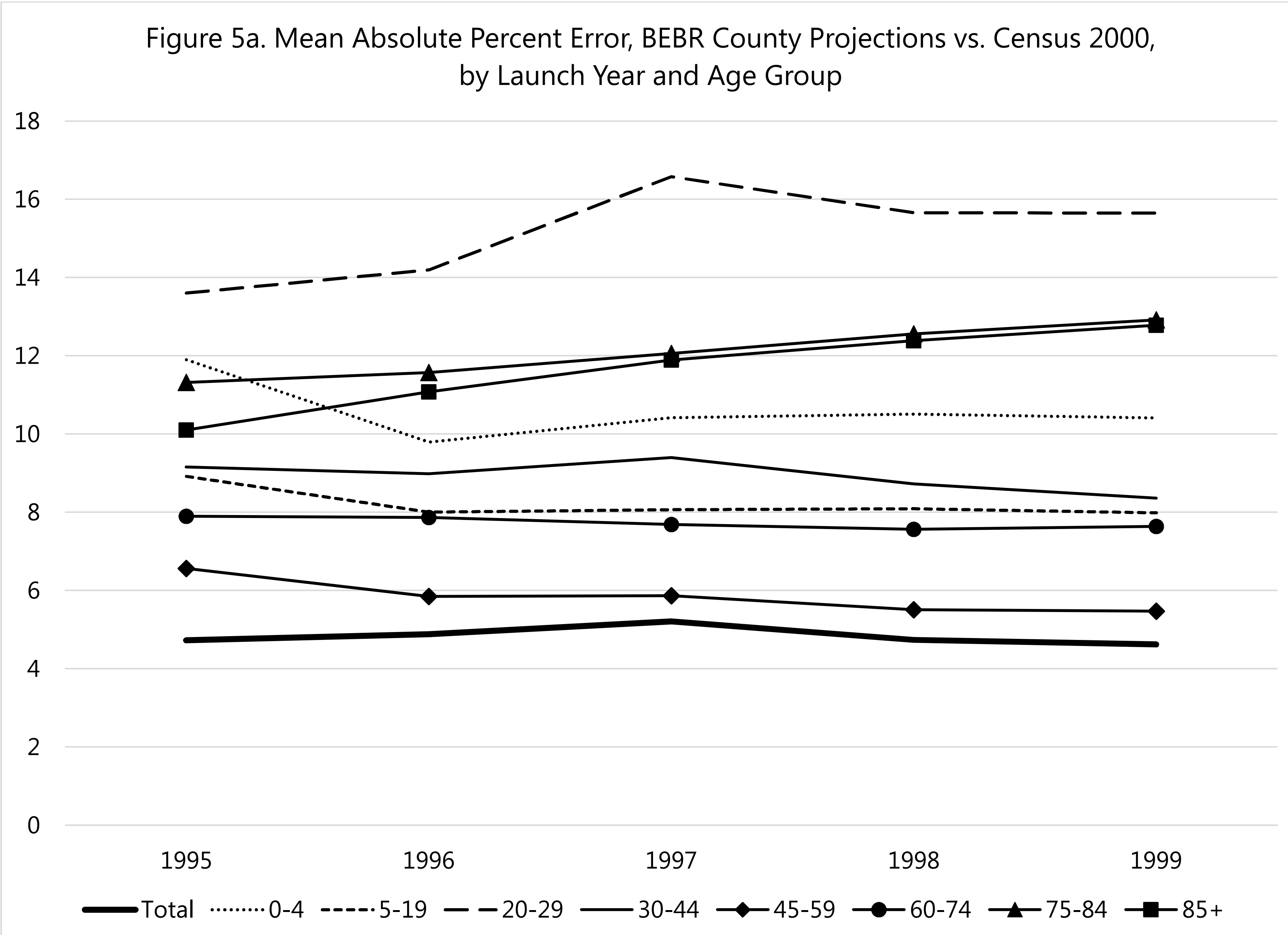
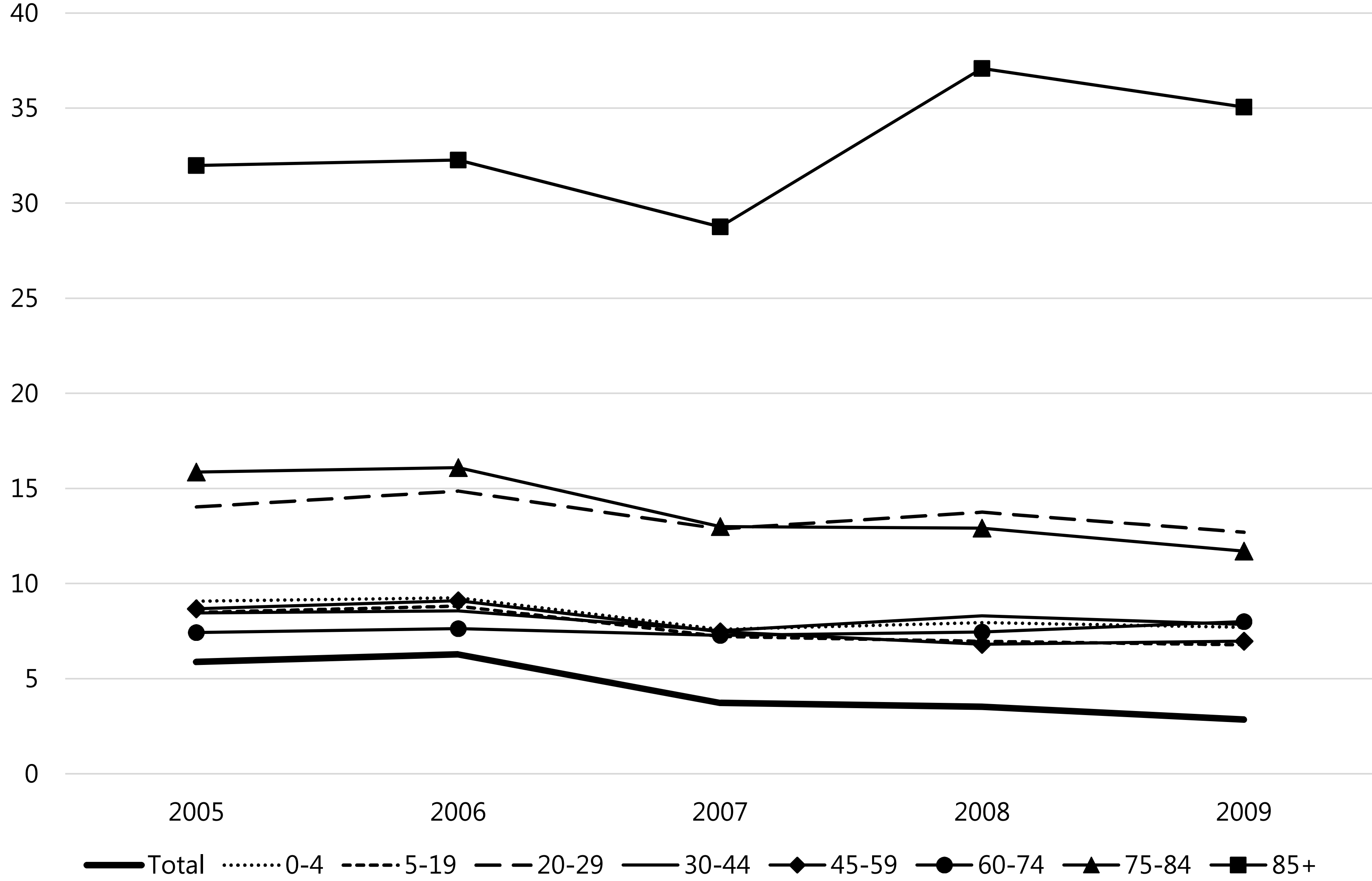


Figure 5a. Mean Absolute Percent Error, BEBR County Projections vs. Census 2000,
by Launch Year and Age Group
18
16
14
12
10
8
6
4
2
0
1995
1996
1997
1998
1999
Total
0-4
5-19
20-29
30-44
45-59
60-74
75-84
85+

Figure 5b. Mean Absolute Percent Error, BEBR County Projections vs. Census 2010, by Launch Year and Age Group



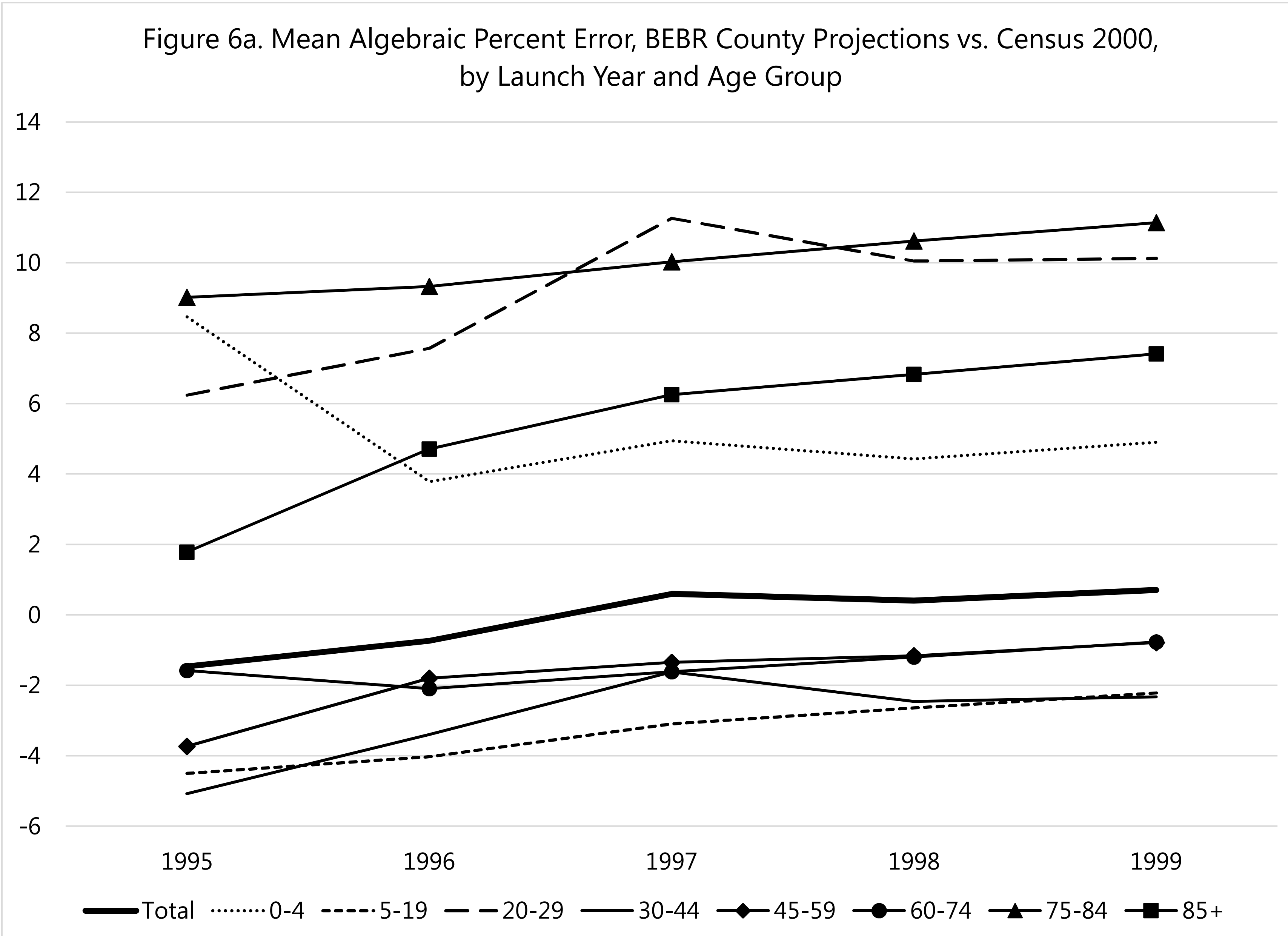


Figure 6a. Mean Algebraic Percent Error, BEBR County Projections vs. Census 2000,
by Launch Year and Age Group
14
12
10
8
6
4
2
0
-2
-4
-6
1995
1996
1997
1998
1999
Total
0-4
5-19
20-29
30-44
45-59
60-74
75-84
85+

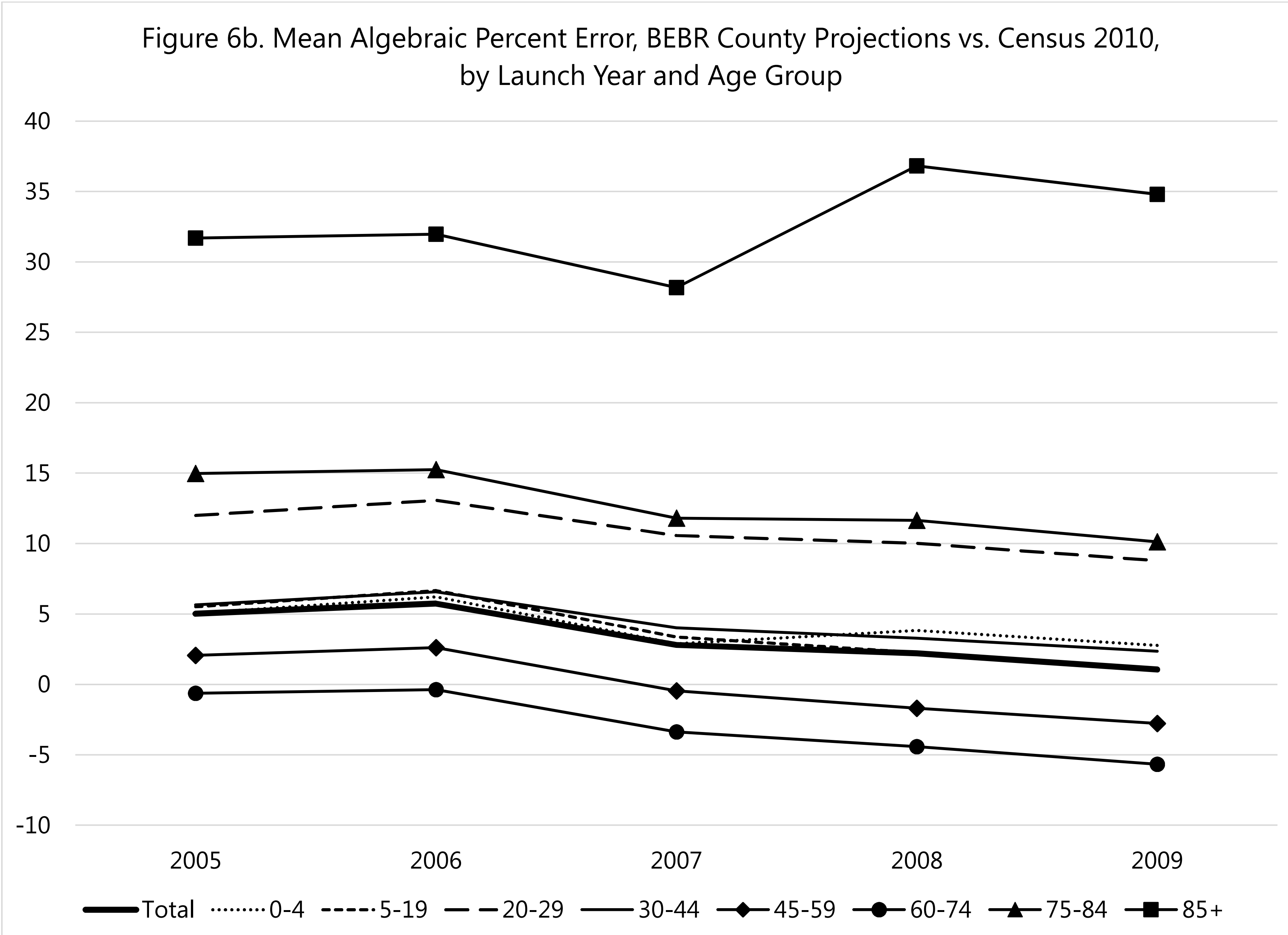


Figure 6b. Mean Algebraic Percent Error, BEBR County Projections vs. Census 2010,
by Launch Year and Age Group
40
35
30
25
20
15
10
5
0
-5
-10
2005
2006
2007
2008
2009
Total
0-4
5-19
20-29
30-44
45-59
60-74
75-84
85+

Table 1a. Mean Absolute Percent Error, BEBR County Projections vs. Censuses 2000 & 2010, by Age Group and Population Size (5 Year Averages)						
	2000			2010		
	Total	<100,000	≥100,000	Total	<100,000	≥100,000
Total	**4.8**	**6.5**	**3.1**	**4.4**	**4.5**	**4.4**
Ave	**9.4**	**12.1**	**6.5**	**10.6**	**13.3**	**7.8**
0-4	10.6	13.9	7.1	8.3	8.9	7.7
5-19	8.2	9.3	7.0	7.7	9.2	6.1
20-29	15.1	21.0	9.0	13.6	19.7	7.5
30-44	8.9	10.2	7.5	8.1	9.6	6.7
45-59	5.9	7.9	3.7	7.8	9.7	5.9
60-74	7.7	10.5	4.7	7.6	9.7	5.4
75-84	12.1	17.0	6.9	13.9	17.8	10.0
85+	11.6	14.7	8.4	33.0	41.1	24.8

Table 1b. Mean Algebraic Percent Error, BEBR County Projections vs. Censuses 2000 & 2010, by Age Group and Population Size (5 Year Averages)						
	2000			2010		
	Total	<100,000	≥100,000	Total	<100,000	≥100,000
Total	**-0.1**	**1.6**	**-1.8**	**3.4**	**3.2**	**3.5**
Ave	**1.1**	**3.3**	**-1.1**	**5.5**	**6.6**	**4.5**
0-4	5.3	9.2	1.2	4.2	3.4	4.9
5-19	-3.3	-1.9	-4.7	3.8	4.9	2.6
20-29	9.0	15.9	1.8	10.9	17.6	4.1
30-44	-3.0	-1.6	-4.4	4.4	6.3	2.5
45-59	-1.8	-2.4	-1.1	-0.1	-3.8	3.7
60-74	-1.5	-1.8	-1.0	-2.9	-5.2	-0.5
75-84	10.0	15.1	4.6	12.8	16.1	9.3
85+	5.4	11.1	-0.6	32.7	40.9	24.3

Table 2. Comparison, Medicare Enrollment Adjustment, 2006 Set of BEBR County Projections vs. Census 2010 (n=58)							
	Age 70-74						
	MAPE				**MALPE**		
	Total	**Male**	**Female**		**Total**	**Male**	**Female**
No Adjustment	7.0	8.1	8.7		3.5	0.3	6.9
Adjustment	6.0	7.4	7.1		1.3	-1.8	4.5
	Age 75-79						
	MAPE				**MALPE**		
	Total	**Male**	**Female**		**Total**	**Male**	**Female**
No Adjustment	13.2	11.7	15.7		13.1	11.1	15.2
Adjustment	10.9	9.6	13.2		10.5	8.6	12.6
	Age 80-84						
	MAPE				**MALPE**		
	Total	**Male**	**Female**		**Total**	**Male**	**Female**
No Adjustment	22.5	23.3	22.6		22.5	23.3	22.4
Adjustment	19.7	20.4	19.9		19.7	20.4	19.5
	Age 85+						
	MAPE				**MALPE**		
	Total	**Male**	**Female**		**Total**	**Male**	**Female**
No Adjustment	34.7	41.5	32.1		34.7	41.5	31.7
Adjustment	31.8	38.3	29.3		31.7	38.3	28.8