Title: The Change in U.S. Average Household Size Attributable to Population Aging: Decomposing the Reciprocal of a Demographic Rate

Author: Mike Hollingshaus, Demographer, Kem C. Gardner Policy Institute, University of Utah; mike.hollingshaus@utah.edu

Abstract

Average household size is a critical measure that impacts government budget allocations and anticipated demand for services. Population age structure affects household size, but little research has examined its historical contributions. This paper decomposes changing average household size, as measured by persons-per-household (PPH), into behavioral and age-structural components. Since age-specific PPH is undefined for children, direct decomposition is impossible. I therefore develop and apply a straightforward method to decompose the reciprocal of a demographic rate. Historical U.S. decennial census data show PPH has decreased monotonically since 1850, and decomposition reveals most of this change (85 percent) can be attributed to population aging. Distinctive patterns appeared during the Baby Boom, and recent trends show a return to dynamics observed during the early 20th century. Results suggest average household size will continue to decrease as the U.S. population ages, a finding that further informs household and population estimates and projections.

Researchers and planners required accurate estimates and projections of both population and households to make good decisions. Whether used directly, or as denominators for calculating rates, these counts impact our understanding of, and preparation for, family living arrangements, health outcomes, utilities, housing, and other critical services. Often, researchers need to move from one unit of analysis to another, which requires a conversion factor. The conversion factor that converts households into household population is called “persons per household” (PPH), which is also a common measure for average household size (Swanson and Hough 2012; Thomas K. Burch 1970). PPH and its reciprocal, the headship rate (HDR), exert great influence over funding and planning decisions (Swanson and Hough 2012).

Understanding trends in PPH should help improve policy and research. Yet, despite having such a large policy impact, the measure receives little attention. Values are often taken directly from published data and implemented without adequately considering the demographic underpinnings. Data irregularities and the potential for small fluctuations to drastically alter findings recommend a cautious implementation (Swanson and Hough 2012). Understand the historical trends and contributing factors can help better interpret such data. This paper examines one critical contributor to PPH trends: population aging.

Household size, as measured by PPH, should decrease as the U.S. population ages. This is because age-specific HDRs correlate positively with age (Leiwen and O’Neill 2004), and PPH is the reciprocal of the household-population weighted HDRs. This pattern is analogous to crude mortality rates, which increase as the population ages because age-specific death rates correlate positively with age. Formal methods of decomposition can be utilized to quantify the extent to which population aging has affected such crude measures. Adapting such methods to consider reciprocal rates, this paper shows that United States PPH has monotonically decreased since 1850, and this decrease has been mostly driven by an aging population structure.

This research becomes more pertinent as recent concerns about a United States affordable housing crisis are brought to the forefront of policy debate (Siegler and Berumen 2018; Rappaport 2017; Wood, Eskic, and Benway 2018). Recent research attempts to delineate reasons for such shifts, with a particular emphasis upon economic predictors (Rappaport 2015; Goodman, Pendall, and Zhu 2015; Paciorek 2016). While some historical research examines the topic (Salcedo Alejandrina, Schoellman Todd, and Tertilt Michèle 2012), the emphasis again is on economic predictors. Since PPH is so strongly correlated with macro-demographic processes (Thomas K. Burch 1970), historical demographic research could help clarify patterns and expectations.

All of these discussions hinge upon a solid quantitative understanding of the PPH measure, and therefore I begin with formal definitions and common interpretations. To clarify the measure's import, I then review important uses of the measure, and recent observed irregularities in survey estimates. Next, I detail the method for decomposing the reciprocal of a demographic rate, and apply it to U.S. decennial Census data since 1850. The results show important secular patterns related to the Baby Boom, and recent returns to patterns seen in the early 20th century.

BACKGROUND

The Measures

Persons per household is the reciprocal of the crude headship rate. In practice, however, headship rates are often utilized in their age-specific formulation, and PPH in its crude form. In fact, since practical and definitional issues often preclude the categorization of children as household heads, age-specific PPH is undefined for children. To clarify these relationships, I begin with the following formulations.

Definitions

Let *v(x,t)* be the headship rate for age *x* at time *t*. Also at time t, let *f(x,t)* be the age-specific enumeration of household heads, *u(x,t)* an age-specific measure of PPH, and *w(x,t)* the household population. Note that w(x,t) is not necessarily the entire population, which is the comprised of the household and group quarters populations. The following expressions identify the age-specific measures:

$$v(x,t) = \frac{f(x,t)}{w(x,t)} = \frac{v(x,t)w(x,t)}{w(x,t)}, \qquad (1)$$

$$u(x,t) = \frac{w(x,t)}{f(x,t)} = \frac{w(x,t)}{v(x,t)w(x,t)} = [v(x,t)]^{-1}, \qquad (2)$$

where, *v(x,t)* is a demographic participation rate, or prevalence, defined as a proportion on $0 \leq v(x,t) \leq 1$. This means that *v(x,t)* only exists when the corresponding household population is greater than zero (i.e., there must be a population at risk for the concept of a rate to be meaningful). Therefore, the population stocks are restricted to $0 < w(x,t)$, and $0 \leq f(x,t)$. Finally, $1 \leq u(x,t)$, when $v(x,t) > 0$ and undefined when $v(x,t)=0$, the latter case occurring when nobody in the age-specific household population is the head of a household. This suggests that the age-specific PPH measure is meaningless for groups that cannot head households by definitional restriction, such as children. This might further explain why PPH is not often presented in its age-specific form *u(x,t)*.

The crude persons per household and headship rate measures are defined as

$$\bar{v} = \frac{\int_0^\infty f(x,t)\,dx}{\int_0^\infty w(x,t)\,dx} = \frac{\int_0^\infty v(x,t)w(x,t)\,dx}{\int_0^\infty w(x,t)\,dx}, \qquad (3)$$

$$\bar{u} = \frac{\int_0^\infty w(x,t)\,dx}{\int_0^\infty f(x,t)\,dx} = \frac{\int_0^\infty w(x,t)\,dx}{\int_0^\infty v(x,t)w(x,t)\,dx} = [\bar{v}]^{-1}\,, \qquad (4)$$

for $0 < w(x,t)$, $0 \leq f(x,t)$, $0 \leq v(x,t) \leq 1$, *and* $1 \leq u(x,t)$. Here the "bar" notation reduces clutter and is used to represent a compositionally-weighted average, or crude, rate (Vaupel and Canudas-Romo 2002) . Notice that since, by definition, there might only be one head per household, then the total number of household heads $\int_0^\infty f(x,t)\,dx$ is also a measure of the total number of households. The quantity $\int_0^\infty w(x,t)\,dx$ is the total household population. Note that while children cannot head households, they are included in the numerator of the crude PPH (4), which has led some researchers to suggest alternative behavioral measures of household size (T. K. Burch 1980).

Since the rates are reciprocals, an increase in one equates to a decrease in the other. Note that, in practice, discrete data are used to estimate the quantities. By way of illustration, in discrete notation, (3) is written as

$$\bar{v} = \frac{\sum_{x=0}^{\infty} f_{x,t}}{\sum_{x=0}^{\infty} w_{x,t}} = \frac{\sum_{x=0}^{\infty}\left[v_{x,t}w_{x,t}\right]}{\sum_{x=0}^{\infty} w_{x,t}}\,. (5)$$

The continuous notation is conceptually appealing because, akin to other demographic phenomena, the age-specific householder rates can be assumed to change gradually with age.

Figure 1 illustrates historic PPH for the U.S. from the decennial census (Ruggles et al. 2018). Similar data have been presented by other researchers (Salcedo Alejandrina, Schoellman Todd, and Tertilt Michèle 2012). The measure has monotonically decreased since 1850, meaning households have been getting smaller. The pace of decline appears to have slowed in the last few decades, and these time patterns are considered in greater detail later.

Using the same data source, Figure 2 charts age-specific headship rates at 20-year intervals since 1920. Beneath age 15, the rates are effectively zero. They increase fairly rapidly during the next 10 years of life, though this pattern has been more pronounced since 1960. Interestingly, the young adult rates for 2000 were lower than for 1980, suggesting a possible reversal. Rates between ages 40 and 60 are generally between 50 and 60 percent. In older ages, rates begin to decline—but, the age of onset appears to be increasingly postponed.

*Interpretation*s

Crude PPH is the average size of a household, and roughly measures the tendency for people to live in groups. Age-specific PPH is conceptually ambiguous. The crude PPH measure is the average number of persons in a household comprised of multiple persons of potentially different ages, which is an actual population parameter one might estimate. Age-specific PPH is interpreted as the average number of persons in a hypothetical household comprised of persons all identically aged, which is unlikely to be to be empirically encountered.

In contrast, HDRs are often utilized in their age-specific form and behaviorally interpreted as the desire for individuals to form their own households, with higher rates indicating a desire to live apart (Goodman, Pendall, and Zhu 2015; T. K. Burch 1980) . These interpretations are often utilized in contexts conjunction with work on “generations,” such as anticipating the housing preferences of Baby Boomers or Millennials (Rappaport 2015). However, as Figures 1 and 2 illustrated, some age-specific demographic patterns for the US are fairly consistent over time, and might be readily interpreted in a life-course framework.

For young adult populations, a higher rate might reflect a spirit of independence and entrepreneurship that impels one to leave their childhood home, and a low rate a potential “failure-to-launch.” During adulthood, higher age-specific HDRs might reflect grown children leaving home, or possibly a greater prevalence of divorce or single-parent households. In late life, higher ASDRs could be interpreted as a desire for independence among older adults, and lower rates cultural norms of multigenerational living possibly structured by gender or race/ethnicity.

However, this facile interpretation ignores external limits, including economic and health constraints. Each household requires a living structure, and therefore household formation is strongly impeded or facilitated by the availability of housing and income. Household formation will be hampered in the presence of insufficient housing supply. When employment or wages are low, people may not have means adequate to obtain housing, unless certain policies or financial instruments make housing more affordable. These dynamics will be reflected in age-specific HDRs, regardless of population preferences or behavioral norms.

Older adults might be disproportionately affected by health constraints that constrain the possibility of living alone. Such health limitations on independent living could operate indirectly by limiting the ability to obtain the resources necessary for housing, impose high health bills in the absence of adequate insurance, or more directly through an actual inability for independent care. While such circumstances might be more common to older adults, health issues can limit the life chances for someone of any age. Recent research suggests an increase in the prevalence of multi-generational households as grandparents and other extended family help raise children whose parents are affected by the opioid epidemic (Ho 2018).

Common Demographic Uses and Policy Implications

PPH impacts funding allocations. The US government allocates resources according to Census Bureau population postcensal estimates (Swanson and Hough 2012). These estimates are also used as denominators for the calculation of demographic and epidemiological rates, impacting scientific findings.

For small areas such as cities or tracts, these estimates are implemented with the housing unit method. Residential construction and demolition records are combined with vacancy rates to produce an estimate of occupied housing units. Depending upon structure type (for example, multifamily, single-family, high-density rental), a number of households can be inferred. PPH is then used to convert the household metric into an estimate of household population. These are added to estimates of group quarters from other data sources to produce the total population estimate (Smith, Nogle, and Cody 2002; Swanson and Hough 2012).

HDRs can also affect funding allocations and anticipated planning needs through the household projections they produce via the “headship method” (George et al. 2008) . These projections are used by housing, utility, business, scientists, and other planners to anticipate future trends, possibly through its inclusion as an input in another model (Liu et al. 2003).

In the “headship method,” projected age-specific HDRs are multiplied by a previously-projected age-specific household population (obtained through cohort component projection, for example), to yield an enumeration of households characterized by the age of the household head. The sum of these produces a projected total number of households. The Harvard Joint Center for Housing Studies (JCHS) uses the headship rate method to produce projections of households based upon Census Bureau population projections (McCue 2014). While this is not the only method for projecting households (see, for example, (Zeng et al. 2013)), it is widely used, possibly due to its long history and relatively light data requirements (George et al. 2008). Akin to PPH, HDRs hold considerable leverage over policy planning. Given the drastic policy implications of population counts, such measures are intensely political (Smith, Tayman, and Swanson 2013; Walashek and Swanson 2006).

Recent Inconsistencies in Survey Estimates

The decennial census will provide the best estimate of PPH and HDRs. Two common data sources for more recent data are the American Community Survey (ACS) and the Current Population Survey (CPS). These surveys produce different household estimates (Salcedo Alejandrina, Schoellman Todd, and Tertilt Michèle 2012), partly due to definitional issues, but more likely due to the weighting schemes and external target "controlling" (McCue, Masnick, and Herbert 2015; Swanson and Hough 2012). Unfortunately, these surveys produce not only differing estimates, but different trends.

By illustration, Figure 3 plots PPH as published from the 2000 and 2010 decennial censuses (U.S. Census Bureau 2018c, 2018d), and the 2005 through 2016 single-year ACS (U.S. Census Bureau 2018b) and CPS (U.S. Census Bureau 2018a). Since the estimates are indexed at July 1, but the decennial census values are indexed at April 1, I have assigned years of 1999.75 and 2000.75 for the censuses. The decennial values slightly decrease between the censuses, in line with the pattern already shown in Figure 1. However, this obfuscates variation that likely occurred during the housing boom and bust that precipitated the Great Recession.

The CPS values give a picture consistent with microeconomic theory. During the economic and housing boom, PPH slightly decreased, consistent with the patterns of rapid household formation and employment that occurred immediately prior to the Great Recession. During that recession, PPH started to rise, reaching its peak in 2010. This likely occurred as employment decreased, housing became unobtainable, and people "doubled up" (Johnson 2011) in homes. Since the recovery, the pattern of decline has resumed. Note, since the PPH is a crude rate, these trends will be confounded by population aging, which is considered in greater detail below.

By contrast, the ACS shows PPH increasing since 2005. The 2010 published values were far above the decennial census. Those estimates have only continued to increase. Research suggests the CPS numbers track the decennial censuses more closely (McCue, Masnick, and Herbert 2015). However, consideration of the massive policy implications makes the choice of metric incredibly important.

Small fluctuations in PPH can to produce large differences in estimates. By way of illustration, the 2016 point estimates from ACS and CPS were 2.65 and 2.53, with a difference of 0.12. While this difference may appear small, it translates into large numbers of households. The Census Bureau’s estimates program shows the July 1, 2016 estimate of household population at 315,325,581 (U.S. Census Bureau 2017). Dividing this figure by the respective PPH estimates yields 118,990,785 households from ACS or 124,634,617 households from CPS. Then, the CPS PPH value yields 5,643,832 more households than the ACS value. A difference of 5.6 million households is not trivial, so additional information could help clarify the actual anticipated current and future trends.

In particular, since the headship rates are so strongly patterned by age (Leiwen and O’Neill 2004), PPH should decrease by population aging alone. Quantifying the change on PPH induced by behavior vs. population aging could help clarify expectations. This can be accomplished through formal demographic decomposition.

Decomposition

The goal of demographic decomposition is to separate a change into two additive components: *Change in Demographic Rate = Change in Behavior + Change in Population Composition.* For our purposes, the changing composition of interest is the changing age structure. I first overview decomposition generally, and then introduce a method to decompose the reciprocal of a demographic rate.

General decomposition

Decomposition has a rich history in demographic science, as was thoroughly reviewed in Canudas-Romo (Canudas-Romo 2003). More recent demographic work (Horiuchi, Wilmoth, and Pletcher 2008) has further clarified that the change in any measurement over time might be decomposed into a given number of additive components of its constituent parts, regardless of functional form. The method is commonly used in engineering sciences such as mechanical engineering, and can be solved through numerical integration via the "line-integral" method (Horiuchi, Wilmoth, and Pletcher 2008). However, models with closed-form solutions can help illuminate the underlying dynamics, improve interpretation, and be easier to estimate.

Vaupel and Canudas-Romo (2002) presented a practical general-purpose formula for decomposing changes in demographic rates into additive behavioral and compositional components. The formula is concisely elegant, yet adaptable enough to prove useful for analyzing such diverse phenomena as labor force participation rates (Fürnkranz-Prskawetz et al. 2005), gender-specific suicide patterns (Chen, Kwok, and Yip 2012), and ontogenetic development of senescence in bird populations (Rebke et al. 2010). Here, I adapt the algorithm and notation to the specific problem of PPH and HDR.

First, I review some additional notation. Let a "dot" denote the rate of change with respect to time. For example, the change in age-specific headship rate as defined in (1) can be succinctly referenced as:

$$\dot{v} = \dot{v}(x,t) = \frac{\partial}{\partial t} v(x,t). \qquad (5)$$

Another key notation is the "acute" accent, which indicates the "intensity," or proportionate change with respect to time. For example,

$$\acute{w} = \frac{\frac{\partial}{\partial t}[w(x,t)]}{w(x,t)} = \frac{\partial}{\partial t}\ln[w(x,t)] \qquad (6)$$

denotes the proportionate change in the age-specific household population with respect to time.

Vaupel and Canudas-Romo (Vaupel and Canudas-Romo 2002) proved that the instantaneous change with respect to time can be usefully and elegantly decomposed as

$$\frac{\partial}{\partial t}[\bar{v}] = \dot{\bar{v}} = \bar{\dot{v}} + Cov(v, \acute{w})\,, \qquad (7)$$

where the first right-hand term is the behavioral change, which for present purposes is the average change in age-specific HDRs—referred to as a "level-1" effect. The last term is the change attributable to shifting age structure, as measured by the covariance between the HDRs and proportionate change in age-specific household population size. This is called a "level-2" effect. In reality, unreliable data introduced by measurement error, definitional changes, or any number of sources, could also contribute to the changing crude rate. The artifactual effect is called a "level-0" effect, and would need to be ascertained through other methods.

Decomposing the reciprocal of a demographic rate

The present goal is to decompose the temporal change in average household size into the change attributable to behavior vs. the change attributable to the household population's age structure. Here, behavior is the tendency and ability for people to live together, or, alternatively, the opposite of the tendency and ability for people to form independent households. Since the PPH is undefined for childhood ages, but they still impact the crude rate (T. K. Burch 1980), one cannot apply (7) directly to PPH.

However, one can adapt the method using (4) as follows:

$$\dot{\bar{u}} = \frac{\partial}{\partial t}\{[\bar{v}]^{-1}\} = -[\bar{v}]^{-2}\dot{\bar{v}}\,. \qquad (8)$$

Substituting (7) into (8) yields

$$\dot{\bar{u}} = -[\bar{u}]^2[\bar{\dot{v}} + \ Cov(v, \acute{w})]\,, \qquad (9)$$

where the first term in brackets represents the change in behavior, and the second the change due to age composition (which also accounts for the covariation between age and behavior).

It is worth further examining the relationship between (7) and (9). To adjust for the scale, each of the additive factors must be weighted by a proportionality constant. Also, the signs are reversed—a component that increases a rate will decrease its reciprocal. The greater tendency to form an independent households increases the crude HDR, but decreases the crude PPH. The effects of age-structure are similarly reversed. Note that if the contributing factors for each equation are further scaled to represent percentage changes, the contributions are the same, but simply with reversed signs.

I now proceed to decompose the change in PPH for the US into behavioral and age components.

METHODS

Data came from IPUMS (Ruggles et al. 2018). Public-use microdata for US decennial censuses (1% samples) were obtained for the years 1850 through 2010, except for 1890 (which is unavailable). Ideally, full microdata would be utilized, but they are not publicly available for later years, and the sample sizes are so large as to offer little concern about imprecise point estimates. Variables included *group quarters status*, *relationship to household head*, *age*, and *person-weight*.

After combining the data files, I maintained only those cases where the group quarters status was “Households under 1970 definition.” This was the only household definition that had populated values for all data points, and therefore could be utilized to facilitate reliable crosstime comparisons. The difference in household counts should introduce no bias to the point estimates of household size, unless the alternative definitions of households yield different HDRs.

For each year and age group, the household population was calculated, as was the number of household heads. These were then abridged into 5-year age groups 0-4, 5-9, …, 80-84 and top-coded at 85+. Next, age-specific HDRs were obtained for each sample by dividing the age-specific enumeration of household heads by household population. Crude PPH for each sample was calculated by dividing the total household population by the total number of household heads, and crude HDR was calculated as the reciprocal.

Decompositions were performed using the formula presented in (9). Standard demographic approximations were utilized assuming constant rates of change, as presented in the Appendix of Vaupel and Canudas-Romo (2002). Here, a small adaptation was required. The standard demographic approximation for a function, which utilizes the natural logarithm, is undefined for rates of zero. In such cases, this was remedied by replacing zero rates with a trivial value of 10^{-9}.

RESULTS

The historical PPH for the US was already plotted in Figure 1. To reiterate, there is an apparent monotonically-decreasing trend in household size (though there may have been sporadic periods of increase not captured in these discrete data points).

Figure 3 displays the annual average change during the time intervals. The total change in PPH was divided by the number of years to yield annual averages that were comparable for intervals of uneven length. The speed of decrease varies over time. Patterns in these variations become clearer through the decomposition process.

Table 1 displays the decomposed changes for each time interval. To facilitate comparisons with different time intervals, these are further averaged to annual changes. To ascertain the accuracy of the decompositions, the percentage error between the sum of the decomposed factors and the observed crude change is presented. In all cases they are extremely small—well under one percent—and result from approximating a continuous function with discrete data. The observed PPH changes are also quite small, which tends to inflate very small percentage errors. The absolute errors themselves (not presented) are never exceed 0.00114.

The total decrease in average household size between 1850 and 2010 was 2.81. Most of this (2.39, or 85 percent) was due to population aging, but some (0.42, or 15 percent) was due to behavioral changes. These total decomposed changes were obtained by summing from the period-specific changes, which are also shown in the table. Generally, better results are obtained by summing changes between the smallest time intervals possible (Horiuchi, Wilmoth, and Pletcher 2008). In this case, that equates to the periods between decennial censuses.

To facilitate easier comparison, the period-specific decompositions are displayed graphically in Figure 5. The blue bars show the total average annual changes (the same as were shown in Figure 3). The red bars represent the change attributed to age-structure, and the green the change due to behavior. The red and green sum to the blue. First, note that changing age structure always exerts a downward pressure on household size, the sole exception being during the heart of the Baby Boom in 1950-1960, when high fertility rates increased the childhood population that cannot form independent households.

Trends can be roughly divided into four periods. The first is the end of the nineteenth century, where the speed of decrease was slowing. The second was a period of accelerating decrease that starts roughly in 1900, and the trend appears to continue through the 1970s, interrupted by a drastic reversal between 1950 and 1970. That reversal corresponds to the Baby Boom, when high fertility rates increased the proportion of the population in childhood ages, slowing the decline in household size. The fourth period is since 1980, where the speed of household decline has decelerated. Indeed, between 2000 and 2010, the declines are very slight.

There are many periods where the behavior is tending towards increasing household size, while the age structure still exerts a downward pressure. In such cases, the age-structure changes still outpace the behavioral changes, for an overall decrease in PPH. During the early twentieth century, behavior tended towards increased household size. This may have been partially due to changing population composition in terms of immigration. Immigration from Europe was very high during the period, and immigrants tend to have larger family sizes. Such larger family size behavior would be captured in changing age-specific headship rates, and so the effects on PPH would be considered behavioral (as opposed to aging-related) in the decomposition.

During the post-WWII and Baby Boom years, there appeared to be a reversal of trends, with behavior pushing household size down, and age structure exerting a lesser (or positive during the 1950s) influence. Immigration was very restrictive during these years, and so such changes are likely due to the native-born population increasing their independent household formation. This was the period of suburbanization and strong home-owning incentives (Fetter 2013; Boustan and Margo 2013). It also might further reflect gender equality movements during the 70s, when women were increasingly free to form their own households (Goodman, Pendall, and Zhu 2015; Santi 1990). In short, this appeared to be a heyday for independent household formation behavior.

Since 1980s, the pattern returned to something more reminiscent of the early 20th century, with behavior exerting an upward pressure on PPH, and aging populations still pushing it downward by even more. Decreasing financial resources and income inequality might impel young adults to live with their parents for a longer time period (Goodman, Pendall, and Zhu 2015; Kahn, Goldscheider, and García-Manglano 2013). Increased migration, though from different sending regions, also possibly played a role (Hernandez 2004). Other factors such student debt and the Great Recession might also be implicated (Bleemer et al. 2014; Rappaport 2015).

At no point has average household size measurably increased between successive decennial censuses. While behavioral and aging changes have occasionally exerted opposing forces on the average household size, it has still managed to continually decrease. For the average household size to increase in the 2020 decennial census, as might be suggested by patterns observed in the ACS data, would require a drastic reversal from the historical pattern. Indeed, that scenario would require behavioral change to exert a counteracting influence sufficient to overpower the powerful force of the aging population of Baby Boomers to yield an increasing average household size for the first time in U.S. history.

DISCUSSION

The proposed method for decomposing the reciprocal of a demographic rate performed well for PPH, as demonstrated by very low approximation errors. The method is a straightforward extension of previous decomposition methods, and can therefore be easily extended to any reciprocal demographic rate. The benefit of isolating the contributions from behavioral and population aging factors is primarily improved understanding and interpretation, which would translate directly into improved projections and planning.

Specific results suggest most (85 percent) of the decrease in average U.S. household size since 1850 can be attributed to the changing population age structure. Distinctive patterns between the decennial censuses reveal distinctive dynamics during the Baby Boom, and a more recent return to trends encountered during the early twentieth century. Possible explanations for might include changing patterns of income inequality, gender-specific norms in householding behavior, immigration, and housing policy.

However, decomposition is not designed to determine causal explanations (Gupta 1993). Rather, it describes the change in a variable that might be attributed to its constituent parts. Additionally, decomposition, as with any method, can only perform in accordance with the quality of the data. Changing definitions, and sampling, measurement, and coding errors would be additional contributing factors, but unfortunately cannot be separated from the behavioral and aging components absent additional information (Vaupel and Canudas-Romo 2002).

The results presented in this paper should help researchers and planners by anticipating future trends in average household size, especially in consideration of population aging. Barring some drastic behavioral change, the forthcoming wave of retirement-aged Baby Boomers (Vespa, Armstrong, and Medina 2018) should indeed increase the number of households and demand for infrastructure and services, such as a potentially deficient housing stock (Joint Center for Housing Studies of Harvard University 2014). Achieving an increase in average household size would require population-level behavioral changes that are not empirically observable since at least 1850 in the U.S.

REFERENCES

Bleemer, Zachary, Meta Brown, Donghoon Lee, and Wilbert van der Klaauw. 2014. “Tuition, Jobs, or Housing: What’s Keeping Millennials at Home?” New York: Federal Reserve Bank of New York. https://www.newyorkfed.org/research/staff_reports/sr700.html.

Boustan, Leah P., and Robert A. Margo. 2013. “A Silver Lining to White Flight? White Suburbanization and African–American Homeownership, 1940–1980.” *Journal of Urban Economics* 78 (November): 71–80. https://doi.org/10.1016/j.jue.2013.08.001.

Burch, Thomas K. 1970. “Some Demographic Determinants of Average Household Size: An Analytic Approach.” *Demography* 7 (1): 61–69. https://doi.org/10.2307/2060023.

———. 1980. “The Index of Overall Headship: A Simple Measure of Household Complexity Standardized for Age and Sex.” *Demography* 17 (1): 25–37.

Canudas Romo, Vladimir. 2003. *Decomposition Methods in Demography*. Population Studies. Amsterdam: Rozenberg.

Chen, Ying-Yeh, Raymond C. L. Kwok, and Paul S. F. Yip. 2012. “Decomposing the Widening Suicide Gender Gap: An Experience in Taipei City, Taiwan.” *Journal of Affective Disorders* 136 (3): 868–74. https://doi.org/10.1016/j.jad.2011.09.019.

Fetter, Daniel K. 2013. “How Do Mortgage Subsidies Affect Home Ownership? Evidence from the Mid-Century GI Bills.” *American Economic Journal: Economic Policy* 5 (2): 111–47. https://doi.org/10.1257/pol.5.2.111.

Fürnkranz-Prskawetz, Alexia, Barbara Zagaglia, Thomas Fent, and Vegard Skirbekk. 2005. “Decomposing the Change in Labour Force Indicators over Time.” *Demographic Research* 13 (7): 163–88. https://doi.org/10.4054/DemRes.2005.13.7.

George, M.V., Stanley K. Smith, David A. Swanson, and Jeff Tayman. 2008. “Population Projections.” In *The Methods and Materials of Demography*, edited by Jacob S. Siegel and David A. Swanson, Second. Bingley, UK: Emerald Group Publishing.

Goodman, Laurie, Rolf Pendall, and Jun Zhu. 2015. “Headship and Homeownership: What Does the Future Hold?” Washington, DC: Urban Institute.

Gupta, Prithwis Das. 1993. *Standardization and Decomposition of Rates: A User’s Manual*. U.S. Department of Commerce, Economics and Statistics Administration, Bureau of the Census.

Hernandez, Donald J. 2004. “Demographic Change and the Life Circumstances of Immigrant Families.” *The Future of Children* 14 (2): 17–47. https://doi.org/10.2307/1602792.

Ho, Jessica Y. 2018. “Dual Vulnerability: Parental Absence and Grandparent Caregiving in the Wake of the Contemporary American Opioid Epidemic.” In *Amercian*. Philadelphia.

Horiuchi, Shiro, John R. Wilmoth, and Scott D. Pletcher. 2008. “A Decomposition Method Based on a Model of Continuous Change.” *Demography* 45 (4): 785–801. https://doi.org/10.1353/dem.0.0033.

Johnson, David. 2011. “Households Doubling Up.” *Census Blogs* (blog). 2011. https://www.census.gov/newsroom/blogs/random-samplings/2011/09/households-doubling-up.html.

Joint Center for Housing Studies of Harvard University. 2014. “Housing America’s Older Adults - Meeting the Needs of an Aging Population.” Cambridge, MA: Joint Center for Housing Studies of Harvard University. http://www.jchs.harvard.edu/research/housing_americas_older_adults.

Kahn, Joan R., Frances Goldscheider, and Javier García-Manglano. 2013. "Growing Parental Economic Power in Parent–Adult Child Households: Coresidence and Financial Dependency in the United States, 1960–2010." *Demography* 50 (4): 1449–75. https://doi.org/10.1007/s13524-013-0196-2.

Leiwen, Jiang, and Brian C. O'Neill. 2004. "Toward a New Model for Probabilistic Household Forecasts." *International Statistical Review* 72 (1): 51–64. https://doi.org/10.1111/j.1751-5823.2004.tb00223.x.

Liu, Jianguo, Gretchen C. Daily, Paul R. Ehrlich, and Gary W. Luck. 2003. "Effects of Household Dynamics on Resource Consumption and Biodiversity." *Nature* 421 (6922): 530–33. https://doi.org/10.1038/nature01359.

McCue, Daniel. 2014. "Baseline Household Projections for the Next Decade and Beyond." W14-1. Cambridge, MA: Joint Center for Housing Studies of Harvard University. http://www.jchs.harvard.edu/sites/default/files/w14-1_mccue_0.pdf.

McCue, Daniel, George Masnick, and Chris Herbert. 2015. "Assessing Households and Household Growth Estimates with Census Bureau Surveys." W15-5. http://www.jchs.harvard.edu/sites/default/files/w15-5_mccue_masnick_herbert.pdf.

Paciorek, Andrew. 2016. "The Long and the Short of Household Formation." *Real Estate Economics* 44 (1): 7–40. https://doi.org/10.1111/1540-6229.12085.

Rappaport, Jordan. 2015. "Millennials, Baby Boomers, and Rebounding Multifamily Home Construction." *Economic Review*, no. Q II: 37–55.

———. 2017. "The Large Unmet Demand for Housing." *The Macro Bulletin: Macroeconomic Research from the Federal Reserve Bank of Kansas City*.

Rebke, Maren, Tim Coulson, Peter H. Becker, and James W. Vaupel. 2010. “Reproductive Improvement and Senescence in a Long-Lived Bird.” *Proceedings of the National Academy of Sciences* 107 (17): 7841–46. https://doi.org/10.1073/pnas.1002645107.

Ruggles, Steven, Sarah Flood, Ronald Goeken, Josiah Grover, Erin Meyer, Jose Pacas, and Matthew Sobek. 2018. “IPUMS USA: Version 8.0 [Dataset]. Minneapolis, MN: IPUMS, 2018.” 2018. https://doi.org/10.18128/D010.V8.0.

Salcedo Alejandrina, Schoellman Todd, and Tertilt Michèle. 2012. “Families as Roommates: Changes in U.S. Household Size from 1850 to 2000.” *Quantitative Economics* 3 (1): 133–75. https://doi.org/10.3982/QE76.

Santi, Lawrence L. 1990. “Household Headship Among Unmarried Persons in the United States, 1970–1985.” *Demography* 27 (2): 219–32. https://doi.org/10.2307/2061450.

Siegler, Kirk, and Brian Berumen. 2018. “The New Housing Crisis: Shut Out Of The Market.” NPR.Org. 2018. https://www.npr.org/2018/08/06/629410064/the-new-housing-crisis-shut-out-of-the-market.

Smith, Stanley K., June Nogle, and Scott Cody. 2002. “A Regression Approach to Estimating the Average Number of Persons per Household.” *Demography* 39 (4): 697–712. https://doi.org/10.1353/dem.2002.0040.

Smith, Stanley K., Jeff Tayman, and David A. Swanson. 2013. *A Practitioner’s Guide to State and Local Population Projections*. 2013 edition. Dordrecht ; New York: Springer.

Swanson, David A., and George C. Hough. 2012. “An Evaluation of Persons per Household (PPH) Estimates Generated by the American Community Survey: A Demographic Perspective.” *Population Research and Policy Review* 31 (2): 235–66. https://doi.org/10.1007/s11113-012-9227-8.

U.S. Census Bureau. 2017. “Monthly Population Estimates for the United States: April 1, 2010 to December 1, 2018.” Dataset NA-EST2017-01. Washington, D.C.: United States Census Bureau. https://www.census.gov/data/tables/2017/demo/popest/nation-total.html#par_textimage_2011805803.

———. 2018a. “Current Population Survey, March and Annual Social and Economic Supplements.” 2018.

———. 2018b. “GCT1105: United States -- States; and Puerto Rico Universe: Households, Single-Year 2005-2016.” 2018.

———. 2018c. “GCT-P7: Households and Families: 2000 - United States -- Urbanized Area Population by Size Class, 2000.” 2018. https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=DEC_00_SF1_GCTP7.US97&prodType=table.

———. 2018d. “QT-P11: Households and Families, 2010.” 2018. https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=DEC_10_SF1_QTP11&prodType=table.

Vaupel, James W., and Vladimir Canudas-Romo. 2002. “Decomposing Demographic Change into Direct vs. Compositional Components.” *Demographic Research* 7 (1): 1–14. https://doi.org/10.4054/DemRes.2002.7.1.

Vespa, Jonathan, David M. Armstrong, and Lauren Medina. 2018. “Demographic Turning Points for the United States: Population Projections for 2020 to 2060.” P25-1144. Current Population Reports. Washington, D.C.: United States Census Bureau. https://www.census.gov/content/dam/Census/library/publications/2018/demo/P25_1144.pdf.

Walashek, Paula J., and David A. Swanson. 2006. “The Roots of Conflict over US Census Counts in the Late 20th Century and Prospects for the 21st Century.” *Journal of Economic and Social Measurement* 31 (3–4): 185–205.

Wood, James, Dejan Eskic, and D. J. Benway. 2018. “What Rapidly Rising Prices Mean for Housing Affordability.” Gardner Business Review. Salt Lake City: Kem C. Gardner Policy Institute, University of Utah. http://gardner.utah.edu/wp-content/uploads/May2018HousingReport.pdf.

Zeng, Yi, Kenneth C. Land, Zhenglian Wang, and Danan Gu. 2013. “Household and Living Arrangement Projections at the Subnational Level: An Extended Cohort-Component Approach.” *Demography* 50 (3): 827–52. https://doi.org/10.1007/s13524-012-0171-3.

Tables

Table 1. Decomposition of U.S. Persons per Household with Approximation Errors

Year Range	Change in PPH				Average Annual Change in PPH		
	Total	Behavior	Age Structure	Absolute Percentage Error	Total	Behavior	Age Structure
1850-1860	-0.28012	-0.07551	-0.20465	0.01697	-0.02801	-0.00755	-0.02047
1860-1870	-0.18492	-0.00076	-0.18370	0.25224	-0.01849	-0.00008	-0.01837
1870-1880	-0.12488	0.00270	-0.12758	0.00780	-0.01249	0.00027	-0.01276
1880-1900	-0.25858	0.15595	-0.41505	0.20164	-0.01293	0.00780	-0.02075
1900-1910	-0.17695	0.02883	-0.20576	0.00783	-0.01769	0.00288	-0.02058
1910-1920	-0.16967	0.02780	-0.19754	0.03872	-0.01697	0.00278	-0.01975
1920-1930	-0.20839	-0.00672	-0.20168	0.00843	-0.02084	-0.00067	-0.02017
1930-1940	-0.32502	0.00551	-0.33050	0.01103	-0.03250	0.00055	-0.03305
1940-1950	-0.31251	-0.17936	-0.13373	0.18874	-0.03125	-0.01794	-0.01337
1950-1960	-0.03896	-0.21014	0.17141	0.57862	-0.00390	-0.02101	0.01714
1960-1970	-0.19413	-0.18093	-0.01254	0.33794	-0.01941	-0.01809	-0.00125
1970-1980	-0.36147	-0.12342	-0.23918	0.31307	-0.03615	-0.01234	-0.02392
1980-1990	-0.11598	0.06368	-0.18004	0.32952	-0.01160	0.00637	-0.01800
1990-2000	-0.04219	0.00714	-0.04920	0.31069	-0.00422	0.00071	-0.00492
2000-2010	-0.01652	0.06449	-0.08097	0.26684	-0.00165	0.00645	-0.00810
Total	-2.81028	-0.42074	-2.39071	0.04175	-	-	-
Contribution	100.00%	14.97%	85.07%	-	-	-	-

Figures

Figure 1. U.S. Persons per Household

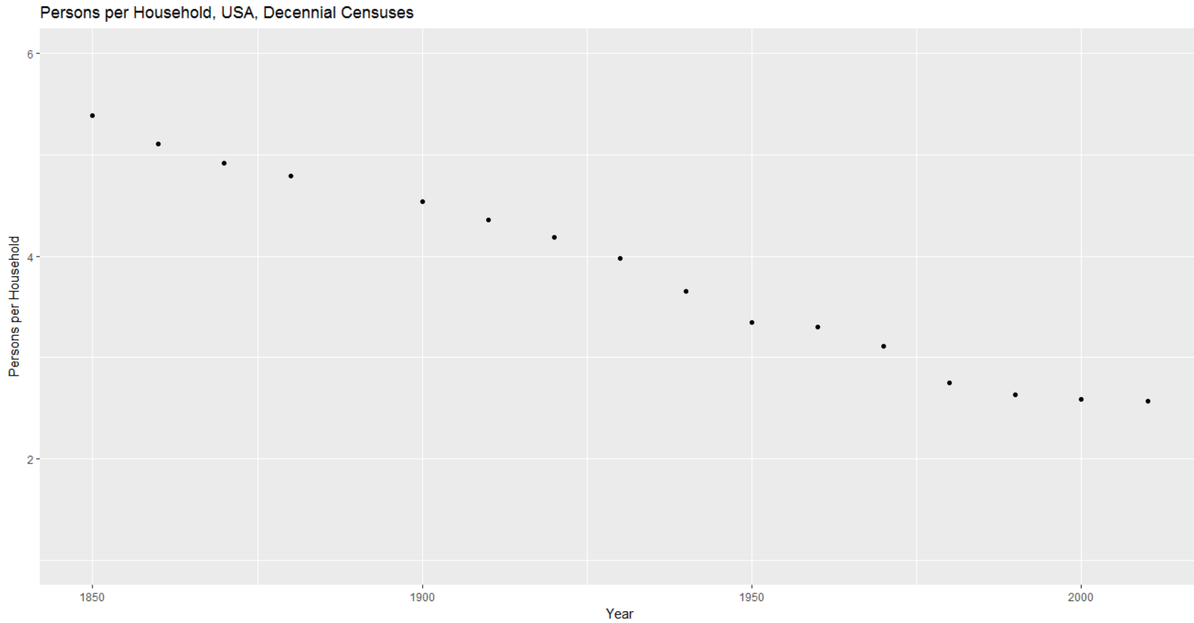

Figure 2. U.S. Age-specific Headship Rates

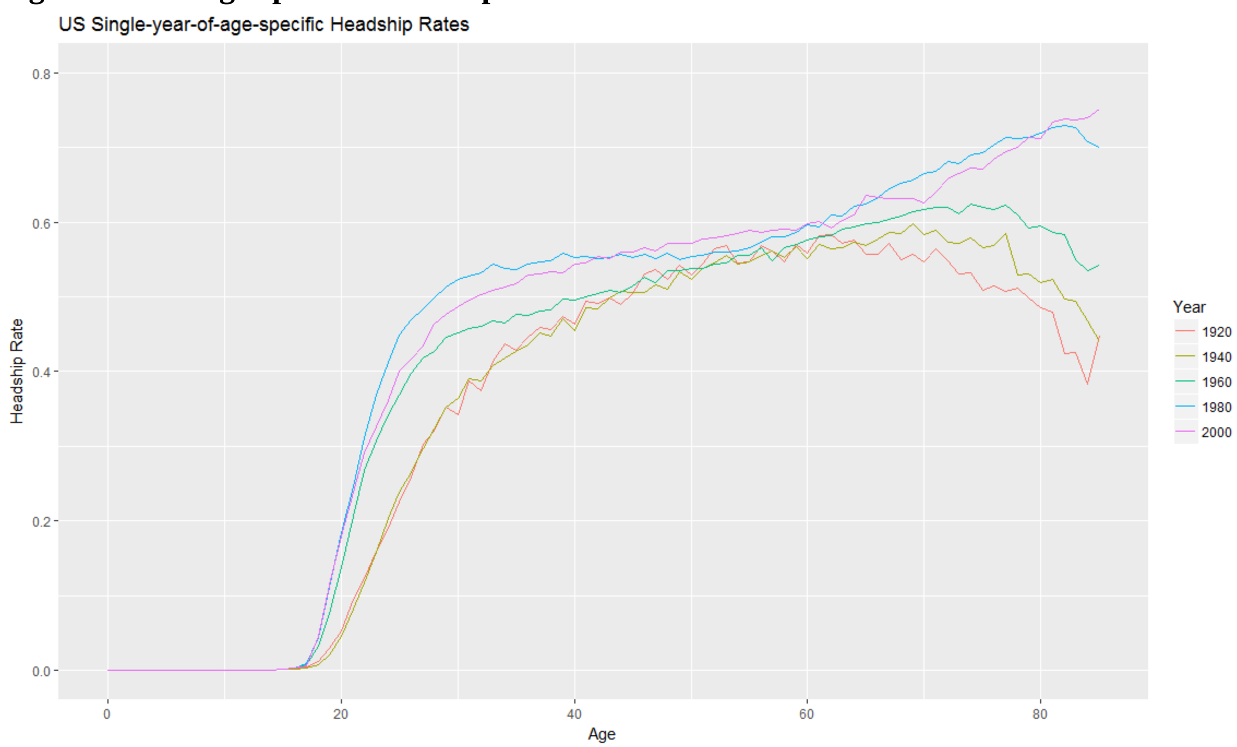

Figure 3. U.S. Persons per Household Estimates from Various Data Sources

Figure 4. Average Annual Change in Household Size, U.S.

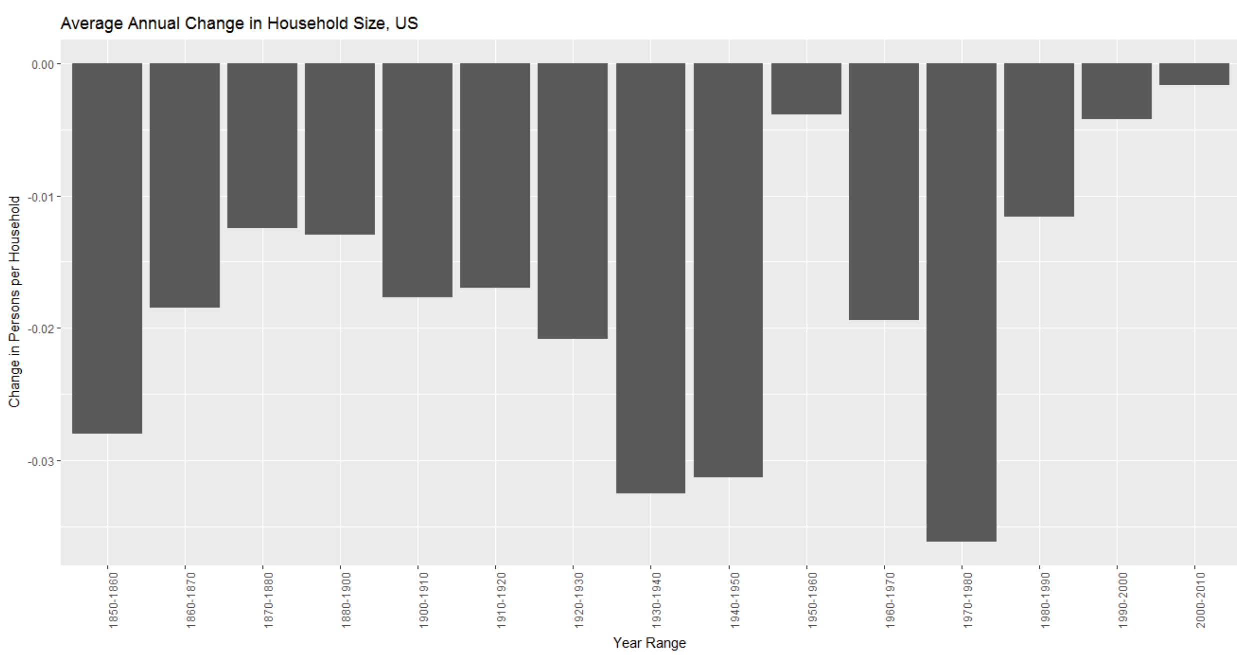

Figure 5. Period-specific Decomposition of Average Annual Change in U.S. Household Size into Components of Behavior and Age Composition