

**THE POPULATION DECLINE OF PUERTO RICO: AN APPLICATION OF
PROSPECTIVE TRENDS IN COHORT-COMPONENT PROJECTIONS^{i ii}**

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ABSTRACT

This paper examines the impact of prospective demographic trends in the population structure of Puerto Rico. Puerto Rico has experienced the first population decline in recorded history, which brings forth the question of the future of the population of the island and what are the policy implications of the transformations of the population. This paper used Cohort-Component Projections, incorporating rates of changes for fertility and mortality based in historical patterns. The net migration rates were calculated using the Residual Method or Vital Statistics Method, and three different scenarios were explored: (1) Full Migration, (2) Half Migration and (3) Zero Migration. Our results point to a continuing decrease in the population of Puerto Rico, even when considering a Zero Migration scenario. Below replacement fertility will still be a key element of this decline, and the prospective trends do not point the declining levels of fertility stopping in the coming decades. Mortality has a consistent and stable structure, even when considering the rates of change for the whole population. Because of this we kept the Survival Rates from the original Life Tables for 2010. The methods employed in our analysis point to a systemic aging of the population of Puerto Rico, the population pyramid gearing towards a state of contraction and to an “inverted pyramid” by 2030. The median age will continue increasing and so will the percentage of persons in the aged age groups. Additionally, we see an increment in dependent population highly fueled by the contraction of the working-age group and the increment in the aged population of Puerto Rico. From a policy perspective, the government of Puerto Rico will have to deal with this population decline and aging in a timely manner should they want to avoid the catastrophic consequences of not addressing the situation in a timely manner.

INTRODUCTION

On 2010, Puerto Rico woke up to an unspoken reality; the population of the island was decreasing (Figueroa-Rodriguez and colleagues, 2012). The 2010 Census indicated that the population of the island summed 3,725,789 persons (US Census, 2010). For the 2000 period the population of the island added up to 3,808,610 persons. A comparison of both census counts evidences the first population decline of Puerto Rico, a decline of 2.17%. The long held expectation that the island would reach 4 million inhabitants dissolved while the government received with surprise the alarming news.

Despite having an unstable trajectory with regards to population growth, a population decline had not been projected by academics, researchers, planning centers or by government authorities. The purpose of this paper is to project the population of Puerto Rico while incorporating trends in the population dynamics as well as to discuss the public policy implications of the population prospects for Puerto Rico. This paper seeks to illustrate the need for better estimates and projections, with the objective of transforming these in tools for policy decision making and guides for economic and social planning.

POPULATION TRENDS 1910-2010

The population trends for Puerto Rico in decades before 2010 had tended to population growth. Despite having a population growth rate that had oscillated between 6% and 20%, this rate never approached the zero growth not the negative growth area (Vázquez-Calzada, 1988). Figure 1 presents the pattern of census counts for the 1910-2010 period and the corresponding growth rates for each period, for specific information please consult Appendix 1.

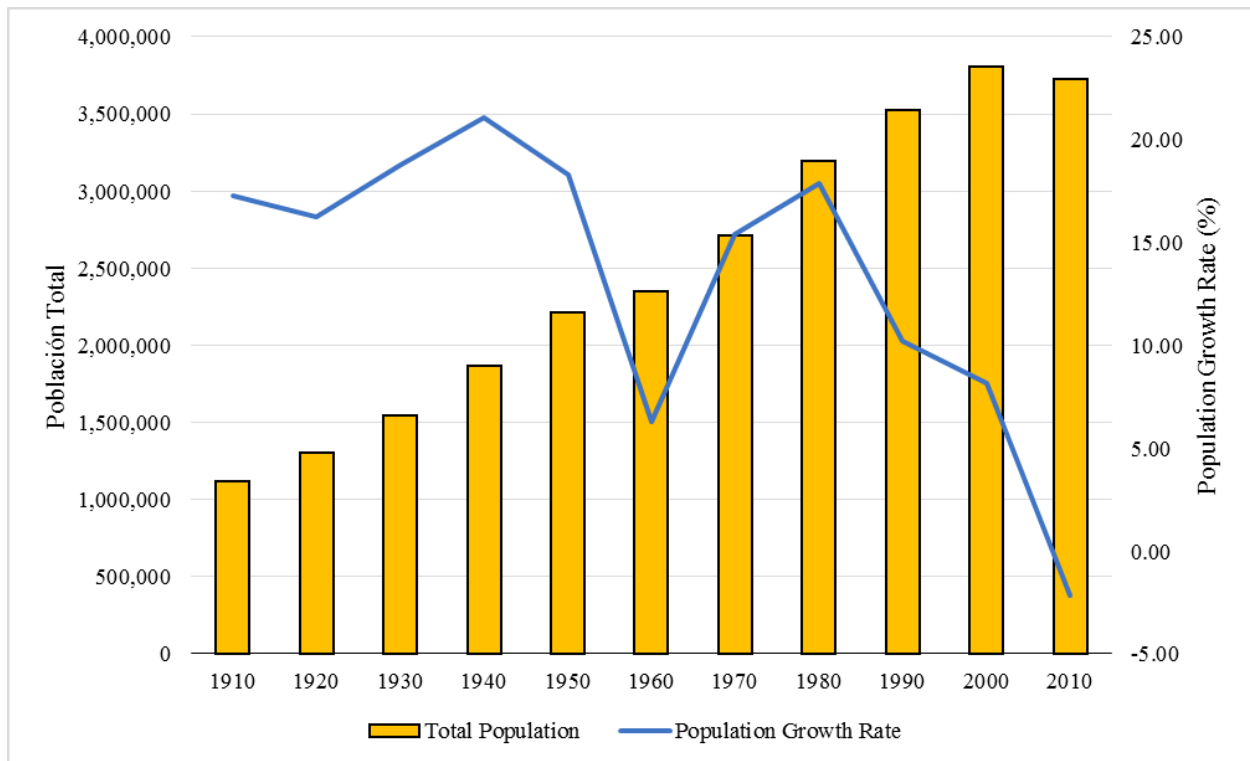


Figure 1 Total Population and Population Growth Rates for Puerto Rico 1910-2010

As it can be appreciated, from 1910 until 1950 the growth rate remained relatively stable and remained over 15%. For the 1950-1960 the growth rate experienced the first deceleration of growth (Myers, 1967). This decline did not happen randomly. During the previous decade the government of Puerto Rico evolved from a colonial system of government to a fully democratic structure resembling the structure of the US Government (Dietz, 1987).

The government structure known as “Freely Associated State” or Commonwealth incentivized the migration of poor population to the United States as means to escape their economic conditions with promises of better jobs, and social welfare in the mainland. The availability of agriculture, manufacture and industrial sector were the primary drivers of this mass migration to the United States during that decade (Maldonado, 1979). This mass migration of Puerto Ricans was possible because the United States Congress extended citizenship to all persons born in Puerto Rico under the Jones Act of 1917 (Rivera-Batiz and Santiago, 1998;

Senior, 1958). At the beginning of the 1960s, Puerto Rican communities or “colonias” existed in states like New York, New Jersey, Illinois and California (Hernández-Alvarez, 1968).

On the subsequent decades the patterns of population growth returned to the over 15% level. After the 1980s, the population growth of Puerto Rico experienced a deceleration which has continued until our days. Despite the intensification of the deceleration of growth no one expected a population decline to happen in 2010 (Figuroa-Rodríguez, 2013). Using arithmetic extrapolative techniques the population growth rate for the 2000-2010 should have been between 4.7% and 7.5%. Even when allowing a 95% error in this measurement, the rate did not approach the zero growth level. This accentuates the need to closely watch the population trends of our places of study to develop better population estimates and projections.

Figure 2 presents multiple population estimates by the US Census Bureau and the Puerto Rico Planning Board and the population counts for 2000 and 2010. As it can be appreciated, the population of Puerto Rico was estimated for 2009 and 2010 to be close and over the 4 million ceiling. These estimates were used to assign government resources for projects including: 1) building and modernization of schools, 2) borrowing money from bondholders, 3) development and approval of permits for housing projects. These examples relied heavily in a growing population to be sustained. At the end of the decade the government noticed a yearly decrease of 16,500 students attending public school (Cámara de Representantes, 2012), the government projections for tax revenues were not met even with the amendment of tax measures and the approval of additional taxes and 30,000 houses remained in the market without any potential buyer (Cámara de Representantes, 2012). This scenario tied to the preliminary results of the US Census was a call for a revision of previous population estimates and of the assumptions behind them.

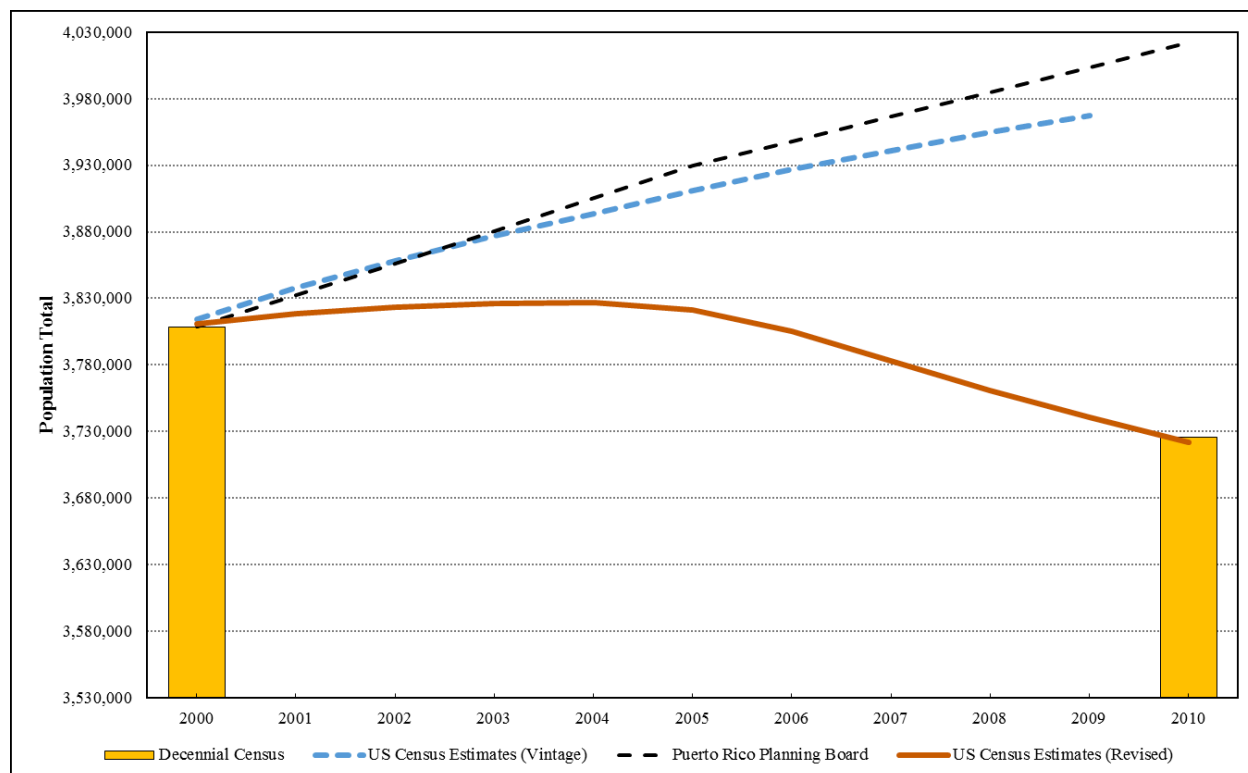


Figure 2 Population Counts for 2000 and 2010, and Population Estimates 2000-2010

A meticulous revision of the assumptions using the Puerto Rico Community Survey (PRCS), allowed identifying two crucial elements in this population decline: (1) the decline to fertility to 1.6 children by women, indicator that had remained below replacement in 2000 where it was calculated to be 2.04 children by women (Departamento de Salud, 2012) and (2) the mass migration of Puerto Ricans from the island to mainland United States. The possible drivers of this migration were better job opportunities, and improved social and economic conditions (Figuroa-Rodriguez and colleagues, 2012; Figuroa-Rodriguez, 2013). The net migration for this decade was of -294,442 individuals, which translates in a -7.90% net migration rateⁱⁱⁱ. The US Census decided to recalculate the population estimates in light of the new evidence of a dramatic change in the population dynamics of Puerto Rico (Figure 2, Orange Line). The new estimated pointed to 2004 being the point of inflexion for the population of Puerto Rico, meaning

2005 was the first year when the population decline started, a decline that has stopped in 2015. In 2013, the population of Puerto Rico was calculated to be 3.6 million persons; a number lower than the population count for the 2010 Decennial Census.

Studying the population trends for Puerto Rico, even in 2010 a population decline was not to be expected if we only considered birth rates and mortality rates. As it can be appreciated in Figure 3, even in 2010 the population was expected to grow. This accentuates the role that migration had in the population dynamics of the island for that period. In the current moment the prominent Puerto Rican Demographer, Raúl Figueroa has indicated that this reality is about to change. In the coming years, the mortality rate will be higher than the birth rates, which will further accelerate the population decline of the island. This is captured by incorporating the prospective trends in the fertility component in the population projections.

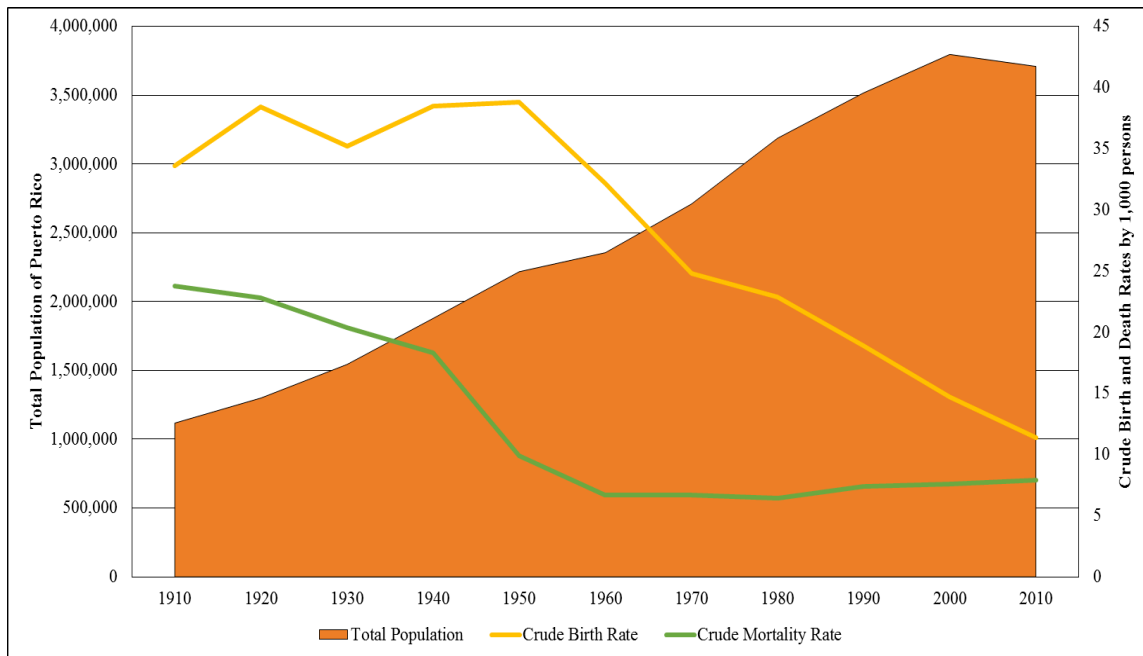


Figure 3 A Demographic Transition approach of the Population of Puerto Rico

The objective of this paper is to project the population of Puerto Rico, while taking in consideration the trends observed in the three demographic processes. Additionally, we will

speak about the projected transformations of the Puerto Rican population in the island in terms of age structure and discuss the implications of these transformations for public policy purposes.

DATA AND METHODS

Data

Data for this study come from multiple sources. Age and sex structures for 2000 and 2010 were obtained from the Decennial Census (US Census, 2000; US Census, 2010). For purposes of the projections the 2000 structure is used as a base year, and 2010 is used as a referent to compare the accuracy of the projections. We will discuss specific sources of information for the demographic processes in each specific section.

Cohort-Component Projections

The Cohort Component Method II depends on the use of three characteristics of population that determine population change, which are also known as the three demographic processes these are: Births, Deaths and Net Migration. For any period the population can be determined using the following equation:

$$P_t = P_o + B - D + (NM)$$

Where P_t is the population at projection period, P_o is the population at base period, B are the births between P_t and P_o , D are the between P_t and P_o and NM is the net migration between P_t and P_o . In the following sections we will explain how each component was incorporated in our projections and how we allowed some variation in the fertility and migration baseline indicators.

Fertility: Prospective Trends

Age Specific Fertility Rates (ASFR) were computed using births by age of the mother for 2000 and 2010. The 2000 ASFRs were used for the projection of population from 2000 until 2010. The numerators for the rates were the births for 2000 or 2010 and the denominators were

the age-specific population counts for each census years. Birth data for the 2000-2010 period were obtained from the Puerto Rico Birth Files published by the National Center for Health Statistics (NCHS). Births were aggregated by five year age groups.

We have incorporated the average rate of change for the fertility rates. According to Rowland (2003) some researchers incorporate the rate of change in the different demographic processes when calculating population projections. According to Dávila (2013) fertility has been decreasing for each decade since the 1970s. According our calculations the fertility rates for Puerto Rico will remain below replacement and continue decreasing in the coming years. The expected fertility rates are presented in Figure 4; additionally we present the projected Total Fertility Rates (TFR) in Figure 5.

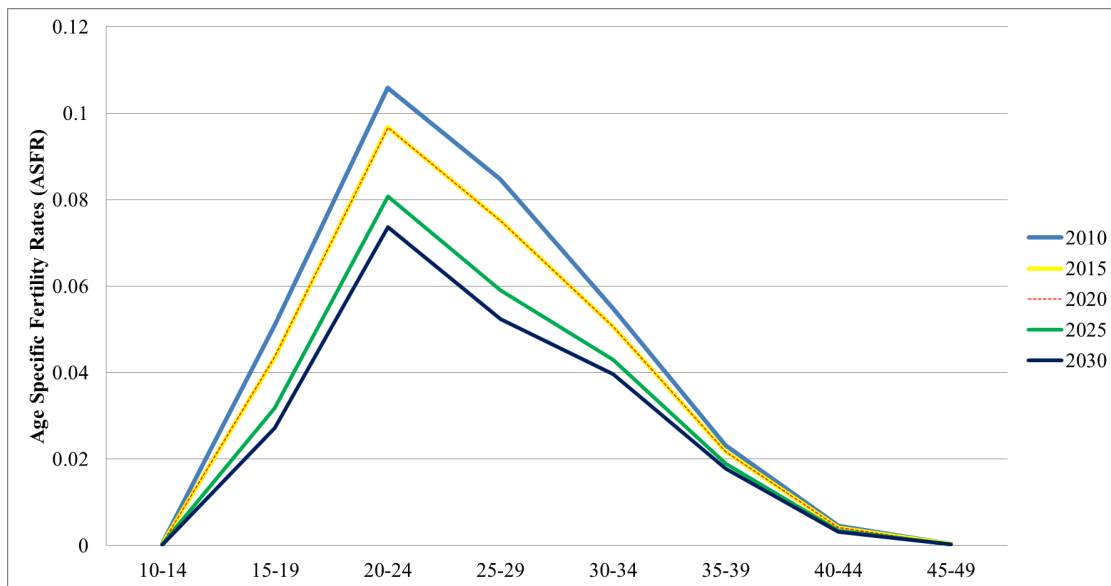


Figure 4 Projected Age-Specific Fertility Rates (ASFR) for Puerto Rico, 2010-2030.

To arrive to our projected ASFR, we used the mean change rate from 2000 to 2010, and used applied half of it to the prospective trends for each ASFR.

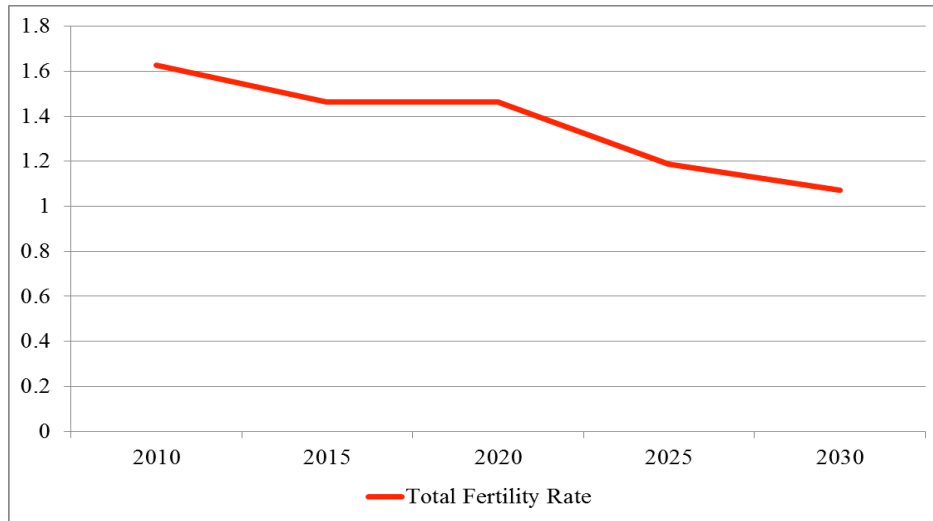


Figure 5 Total Fertility Rate (TFR) based on Prospective Trends for Puerto Rico, 2010-2030

The TFR expected to continue declining in the coming years reducing to 1.07 in 2030. This reduction in fertility, despite being conservative, is likely to impact the future age structure of the population and the overall priorities of the government of Puerto Rico. The future implications will be detailed in the Discussions section.

Mortality: A stable element of Puerto Rican demography

We calculated baseline mortality using the population structure from the 2010 Census. Data on deaths came from the Puerto Rico Death Files from the National Center for Health Statistics (NCHS). We calculated Mortality Rates for each age group and sex, which were incorporated in the life tables and used to derive the Survival Rates for each sex/age-group. To incorporate mortality in the population projections we calculated Sex Specific Life Tables and calculated the Survival Rate for each group. The Life Tables are included in Appendix 2. Figure 6 presents the mortality rates for males and females in Puerto Rico for 2010.

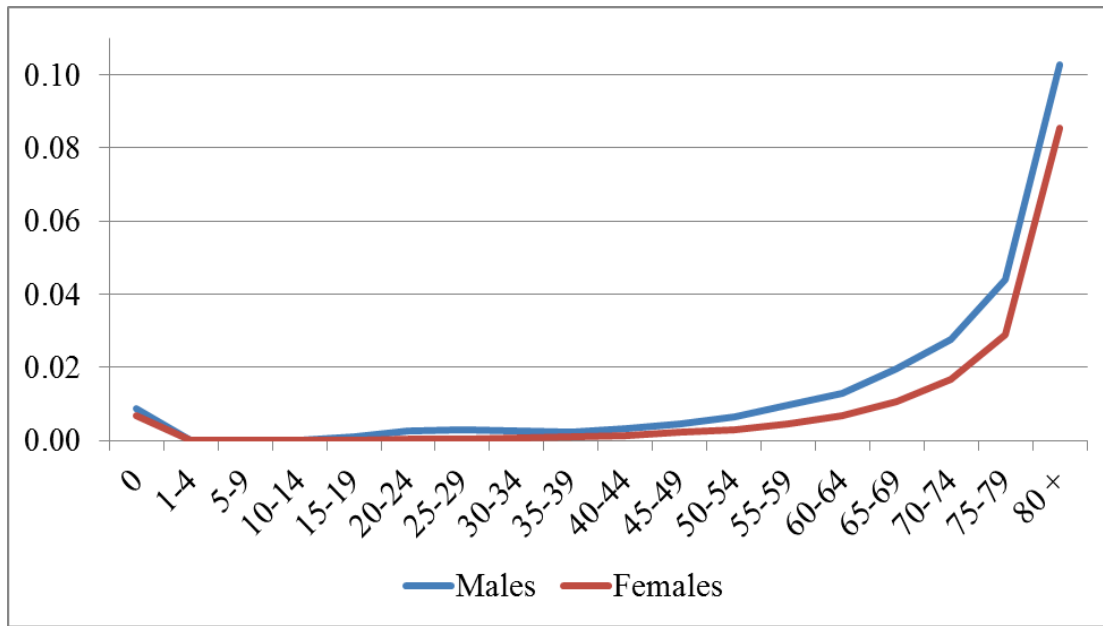


Figure 6 Mortality Rates for Males and Females in Puerto Rico for 2010

Consistent with usual mortality indicators in developed countries, male mortality is higher than female mortality. This difference is present in the young adult ages and more marked in the over 40 year old age-groups. This marked differentials in mortality rates, also translate in differentials in Life Expectancies. According to our life tables males have a life expectancy at birth of 75.38 and females had 83.24 years, these results are very similar to the calculations published by the Puerto Rico Department of Health. The Puerto Rico Department of Health calculated the life expectancies in 2013 as 74.85 for males and 82.56 for females, a difference of half a year and three quarters of a year (Departamento de Salud, 2013).

We did not incorporate a prospective trend change in this scenario because when explored the mortality estimates were found to be very robust and stable with minimal or no change in mortality rates for most age-groups. This means that for our population projections, we will incorporate mortality, through the 2010 Survival Rates obtained from the Life Tables.

Migration: Fluctuating and Different Magnitude Scenarios

Migration was the more complicated component to calculate. We calculated Net Migration Rates through the Vital Statistics Method or the Residual Method. This method starts with a base population (2000) and then subtracts the deaths from each age group (n), proceeds to move forward the age structure (n+1) and add the births as the new zero age group. This is done for all intercensal years and the resulting population is then compared with the decennial count (2010) to calculate the population residual. This component was incorporated to the population projections through a variety of scenarios. Figure 7 presents the population residual or net migration rates calculated using the aforementioned method. .

Migration was incorporated to the population projections through three possible scenarios. The first scenario was full migration, which assumes migration will continue the same level as in the 2000-2010 decade. The second migration is the half migration scenario, which assumes migration will reduce to half of what it was in the previous decade. A final scenario, calculated for purposes of illustrating the effect of migration and deemed to be used as a reference, is a zero migration scenario, where net migration is assumed to be zero.

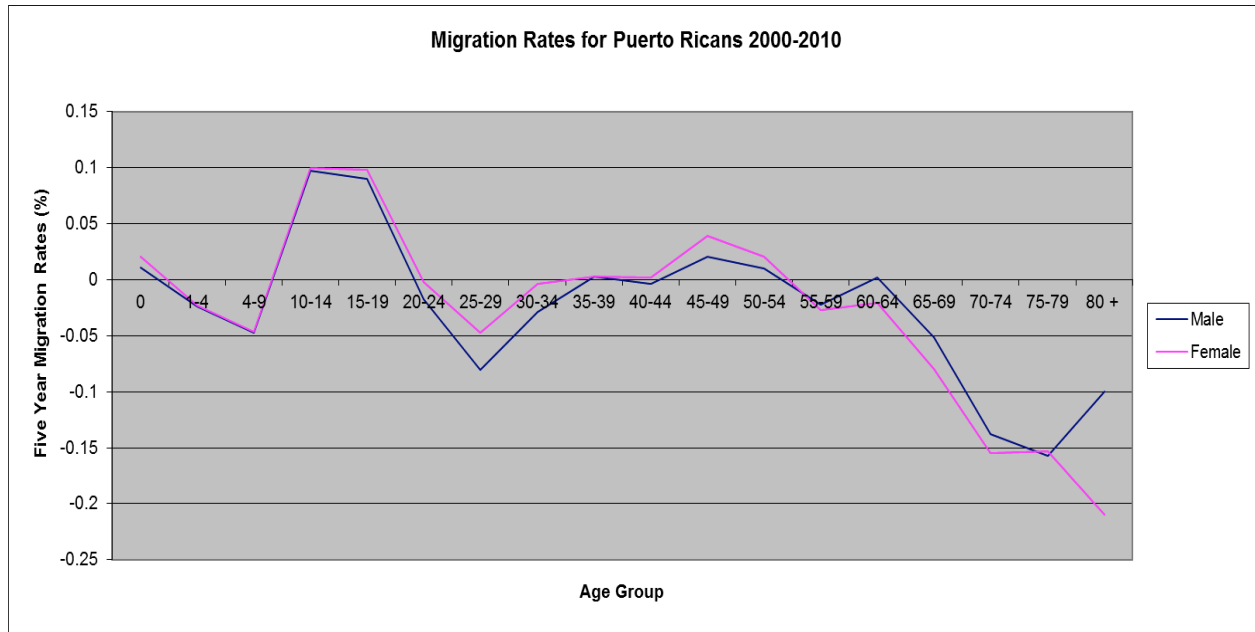


Figure 7 Migration Rates for Puerto Rico, 2000-2010

As it can be appreciated in Figure 7, migration is seen in very similar ways for Males and Females. The current economic crisis (Figuroa-Rodriguez and colleagues, 2012) has acted as a push factor for work-age Puerto Ricans evidenced by the outmigration seen in the 20-30 age groups. An unusual trend is seen in the adolescent populations who have high levels of net migration (positive balance). A previously unaddressed fact is the outmigration (negative net migration) of aged population; this outmigration influences the pace of aging in Puerto Rico by slowing or reducing its magnitude. We have censored outmigration of aged population to 0.10 or 10%, and have incorporated a reduction in the immigration of adolescent population for years after 2010. Apart from those two measures, we only allowed variation in Net Migration Rates by altering the magnitude of the flow of population to the three aforementioned scenarios.

RESULTS

In Table 1 we present the total for the population projections from 2005 until 2030, for the three different migration scenarios. As it can be appreciated by 2030 the population of Puerto Rico is expected to decline below the levels they were in 2000 (3.8 millions). Only the Zero

Migration scenario puts the population of the island above the 2000 level, but this scenario has high levels of error (Table 3) and is not likely to happen as migration has been a constant in Puerto Rican population dynamics since the 1900s. The results of the Zero Migration will not be discussed in detail in this paper. The other two scenarios mark 2015 as the year until which the population of Puerto Rico had potential to grow. After it a marked decline is likely continue and by 2030 the population of the island could reach 3.2 million if the trends continue as projected.

Scenario	2005	2010	2015	2020	2025	2030
Full Migration	3,733,139	3,718,078	3,782,115	3,635,462	3,466,476	3,285,012
Half Migration	3,786,253	3,819,867	3,946,669	3,851,150	3,714,295	3,557,224
Zero Migration	3,826,070	3,900,201	4,086,408	4,034,065	3,945,347	3,836,990

In Table 2, we present the principal indicators of the population projections for the three migration scenarios considered. These are Median Age, % of the Population under 20 and 65 and older, the dependency ratios and the disaggregated dependency ratios for Puerto Rico. Population Pyramids are included in Appendix 3. The 2010, as well as the projected population illustrated in the pyramids point to the population of Puerto Rico entering and having a structure of contraction, which is consistent with the finding of decreasing population, migration seems to play an important role in the pace of the transition to an “inverted pyramid” structure for Puerto Rico. Despite the influence of migration, all scenarios point to an inverted pyramid structure by 2030.

Table 2 Population Indicators for Projected Scenarios, Puerto Rico 2000-2030						
Indicator	Full Migration Scenario					
	2005	2010	2015	2020	2025	2030
Median Age (years)	38.51	39.99	42.70	43.86	45.35	47.24
% Population < 20	24.88	22.91	20.64	19.36	17.67	15.53
% Population 65 +	16.46	17.86	21.63	22.80	23.86	25.02
Dependency Ratio	51.85	52.96	58.21	58.02	56.10	55.55
Child Dependency Ratio	26.86	25.65	23.98	22.00	18.86	16.64
Aged Dependency Ratio	24.99	37.31	34.23	36.03	37.24	38.91
Indicator	Half Migration Scenario					
	2005	2010	2015	2020	2025	2030
Median Age (years)	38.67	40.28	43.31	44.54	46.18	48.10
% Population < 20	24.75	22.74	20.31	19.06	17.31	15.14
% Population 65 +	17.17	19.19	23.59	25.05	26.35	27.64
Dependency Ratio	53.45	55.77	62.48	63.37	61.86	61.54
Child Dependency Ratio	27.10	25.88	24.15	22.44	19.22	16.89
Aged Dependency Ratio	26.35	29.90	38.33	40.92	42.64	44.65
Indicator	Zero Migration Scenario					
	2005	2010	2015	2020	2025	2030
Median Age (years)	38.70	40.34	43.41	44.61	46.10	47.81
% Population < 20	24.70	22.71	20.36	19.21	17.90	16.37
% Population 65 +	17.58	20.01	24.69	26.18	27.35	28.38
Dependency Ratio	54.50	57.66	65.57	67.03	66.44	66.51
Child Dependency Ratio	27.33	26.11	24.69	23.30	20.92	19.25
Aged Dependency Ratio	27.17	31.55	40.88	43.73	45.52	47.26
Source: Population Projections completed using Cohort-Component Method						

According to our projections, the median age will increase in Puerto Rico with migration being influential in this increase. In the case of the Full Migration Scenario, the median age would go up to 47.24 years, 48.10 years for the Half Migration and 47.81 for the Zero Migration by 2030. This indicates that the population of Puerto Rico will be aging; the pace of this increase will be 2 years per decade. In relation to proportions in specific age groups, the diverging trends in the younger than 20 years and the over 65 years old population is notable. Regardless of the migration scenario, Puerto Rico will experience a dramatic reduction in the population younger than 20 years which is highly influenced by the decrease of fertility and the migration of

individuals in reproductive ages. Additionally, the migration trends for the 2000-2010 and the current moment indicate that migration is no longer of an individual but of whole families. The increased number of persons in working and reproductive ages is also accompanied by the migration of their offspring to the mainland United States.

For the other group of interest (population 65 years and older) the projections indicate this sector of the population will be around 25% and 28.4% by 2030 which supports our previous result of the marked increase in Median Age. The migration scenarios play an important role here, in the case where zero migration is considered, the proportion of individuals over 64, is close to becoming 30% of the population, whereas in the other two scenarios this sector of the population remains lower than 28%. A previously non-noted trend in the migration dynamics of the island is the migration of persons who are over 65 years old. According to our calculation the migration of individuals in these age groups fluctuate around between -16% and 0% for specific age groups, with an increased level of outmigration found for individuals over 70 years old. We will speculate about this particular trend in the next section of this paper.

The final indicator presented in Table 2 deals with the Dependency Ratio. The dependency ratio gives us a notion of how many persons are not likely to be active in the economic/labor market versus the number of individuals who are in highly productive ages in terms of labor force participation and economic activity. The disaggregated ratios also provide an idea of how each component of the ratio is behaving as time passes. From a 51.85 dependency ratio for 2005, the lowest found in the Full Migration scenario, this ratio increases to 55.55 persons by 100 persons in the working age group. In the case of the Half Migration scenario, the dependency rate goes from 53.45 persons by 100 persons in the working age groups to 61.54. The increment in the dependency rate is fueled by the aging of the population of Puerto Rico,

which has been discussed previously by ways of the proportion of individuals in the under 20 and over 64 age groups. The results for the Zero Migration are also presented in Table #. When considering the independent effect of each component of the Dependency Ratio, we found that the changed in the overall Dependency Ratio is heavily influenced by the increase in the Aged Dependency Ratio and by a decrease in the Child Dependency Ratio. This increase of the Aged Dependency Ratio is greater than the decrease of the Child Dependency Ratio. The implications of these results for the public and private sectors, as well as for public policy purposes will be developed in the Discussions section of this paper. Detailed sex-specific projections are included in Appendix 4.

Measurement of Errors for Population Projections

Our projection strategy was to use the 2000 population structure as a base year and to project the 2005 and 2010 using our assumed fertility, mortality and migration scenarios. The total count for the projections was compared with the 2010 Census Count for purposes of understanding the margin of error of our projections.

We use the Mean Percent Error (MPE) as a measure of error. The MPE is a measure of the percentage of population under or overestimated in comparison to a known value in this case the decennial census count. The results for the evaluation are presented in Table 3.

Table 3 Mean Percent Error (MPE) for Population Projections			
Scenario	2010 Projection	2010 Census	Mean Percent Error
Full Migration	3,718,078	3,725,789	-0.21
Half Migration	3,819,867	3,725,789	2.53
Zero Migration	3,900,201	3,725,789	4.68

As it can be appreciated the Full Migration Scenario closely projects the total population with an underestimation of less than one percent (-0.21%). In the case of the Half Migration and the Zero Migration, these scenarios overestimate the total population of Puerto Rico by 2.5% and

the 4.63%; this indicates that the zero migration scenario should not be considered when using projections for public policy and planning decisions. Despite these marked level of error, the population structure indicators are fairly similar for the three scenarios. In future cases the half migration and full migration should suffice in terms of projection scenarios being considered.

DISCUSSION

The decline and systemic aging of the population of Puerto Rico has important implications for in the economic stability of the island. The common elements of major economic theories have the population as a factor that can influence the supply and demand of services and products (Parkin, 2015). Furthermore, taxation policies consider population size and structure important for purposes of taxes. An increase in the dependency rates has been correlated with a decrease in tax rates and tax revenues (Razin and colleagues, 2001). From this perspective, we understand that the demographic trends observed in our projections will have numerous implications if they are not addressed in a timely manner.

The first implication is the added pressure to public funded health, long term care, and insurance and welfare support programs for older population. The government of Puerto Rico funds numerous programs to help older population cope with their medical and social needs. One of these programs is healthcare reform, older population use the Puerto Rico Health Insurance (“*la reforma*”) as means to obtain medicines, primary and specialist care. Even in today’s paradigm the PR Healthcare Reform has been found to have low levels of stability, and the government has not been able to deal with the increasing amount of expenses that come from the need for more services of the aged sector of the population (Santos-Lozada, 2012). The likelihood of the aged population continuing to rely in this insurance for their health needs is likely to continue or increase in the coming years.

The shift to chronic illnesses such as heart conditions, strokes, chronic obstructive pulmonary disease, Alzheimer, and conditions related to diabetes are likely to increase with the aging of the population. These diseases do not have a cure, meaning persons and physicians will have to shift their priorities to coping and living with the diseases instead of eliminating the illness. Additionally, the Puerto Rico Healthcare System will have to start caring for persons with multiple diseases, which will pose as a challenge for purposes of financing public health insurance like the one that is in place. A more overarching discussion of these trends and their implications are found in Wiener and Tilly (2002) where they approach the situation of population aging in the case of the United States.

The emergence of an aged sector of the population will undoubtedly be accompanied by the emergence of long-term care centers, for persons who are coping with terminal diseases or whose offspring and family are not able to take care of. A recent presentation by Santos and Marazzi (2014) pointed to the population living in long-term care centers increasing in Puerto Rico during this decade.

In terms of income, the aged population of Puerto Rico has been found to be highly dependent on income supplements and pension systems. A study by the Puerto Rico Catholic University has found that 39% of the aged population lives below the poverty level in Puerto Rico. The heavy dependence on public pensions and income supplements highlights the vulnerability of this population to the economic instability of the government.

The Puerto Rico government has found it difficult to meet their financial obligations during the last 2 years. A battery of financial reforms to Public Employee (Puerto Rico Act 3, 2013), Teachers (Puerto Rico Act 160, 2013) and Judge (Puerto Rico Act 163, 2013) Retirement Systems have either not solved the financial crises of the retirement systems or have been

declared unconstitutional by the Puerto Rico Supreme Court. This last fact adds more pressure to the government as a big sector of the population (“baby boomers”) will be retire in the coming years thus aggravating the delicate situation of these pension systems. The increase in the dependency rate will further aggravate the economic conditions and stability of these retirement systems as well as of welfare income supplements for the elderly and the poor.

The population 65 years and older will require modifications in the services requested and available for this sector of the population. Health services are a priority in this list. Some questions that need to be addressed by the government and the policymakers include: (1) Is the public health insurance able or prepared to finance more beneficiaries who will need more services?, (2) Do health facilities and medical offices have the appropriate infrastructure and specialized staff to provide quality services for this increasing sector of the population?, (3) Does work-age population will be able to undertake or sustain the older sector of the population?. Regardless of other questions we can postulate the implications of an aging population in Puerto Rico requires a strategic plan which incorporates the demographic change and how we will address these challenges in the short and long terms.

A drastic reduction in school-aged children will undoubtedly bring challenges to the current structure of the government and the Puerto Rico Education System. At the moment in which this paper is being written the government deals with a drastic reduction in school-aged children and with a big education system. Since 2011, the government has merged education regions, consolidated schools and even closed teaching institutions. In 2014, 4,000 teachers were identified as at risk of not having students to teach, this represents a 10% of the faculty of the public education system of the island. Despite the drastic reduction in school-aged children education faculties continue to recruit students in higher numbers, a growing proportion of these

students end up working as teachers in states like Texas, Oklahoma, Florida, New York or Pennsylvania.

Currently the Puerto Rico Department of Education (PRDE) has a budget of 3.6 billion dollars this is more than the total budget of some Latin American countries like Dominican Republic. The significant reduction in the number of school-aged children will undoubtedly bring forth challenges for the future of the PRDE. Either the government will have to reduce the number of teachers and schools or they could refocus their resources into education with a lower teacher-to-student ratio which has been consistently associated with positive outcomes in student learning. The current trend indicates the Puerto Rico Department of Education has taken the first option.

Finally, the history of Puerto Rico has been marked by constant migration. During the last decade, the out-migration increased, the migration rates shown before in the paper suggest a negative balance for the young adult and adult population (20-30 years). According to the American Community Survey (ACS) the median age for emigrants oscillates between 27 to 30 years (Rodriguez Ayuso and colleagues, 2011). The lack of opportunities in the labor force for the young adult population is a principal force behind this migration trend. Even in the situation, we should measure quality of job opportunities and improve them in order to slow down the pressure thus reducing the outmigration. An implication of the young adult outmigration is this group also belongs to the reproductive age influencing the decrease in the fertility rates and as a consequence we project a significant reduction under 20 years from 24% to a projected 15% by 2030.

For purposes of public policies the government of Puerto Rico has relied in the approval of new taxes to meet their financial obligations. The taxes have a regressive effect in the economy and act as push factors in terms of migration of the population. A clear example was the taxation to petroleum or “*la crudita*”, after a tax was imposed in 2013, it was revised and increased in 2014 because the projected revenues were not met and were already assigned to the Puerto Rico Department of Transportation and Public Works. As of today the reduction of population is highly influential in the decline and shortage of tax revenues.

We understand that the issues of population decline and population aging have to be addressed immediately by the government of Puerto Rico. The measures should be geared towards coping with an increasing sector of the population that will need more support in terms of social welfare, income support, protections and to protect the stability of the pensions of these populations. Additionally, the failure to meet tax revenue projections should also be understood as a population issue instead of a tax evasion or a contraction of the economy. A decreasing taxable base (populations being taxed) will translate in lower revenues even if taxes are raised or more taxes are approved. The population element/dimension of public, welfare and economic policies should not be ignored in future efforts to deal with the economic crisis of Puerto Rico.

LIMITATIONS

We identified three key limitations for our study. The first is that Puerto Rico stopped collecting race/ethnic backgrounds after the 1990 Census. The decision based in the notion that “we are all Puerto Ricans” has left a gap in how we can address and understand transformations based in the ethnic background of the population of the island. A step forward could be to start collecting this information not only in special forms in the Decennial Census but also in birth and death certificates, as well as in future population based surveys. Policy makers should rescue the

ethnic background categories that reflected the historical and demographic roots of some sector of the population.

The second limitation we found was with the calculation of net migration rates, although we performed various sensitivity analyses we relied on actual trends and non-published information to allow some variation in the migration rates for the post-2010 years. This allowed us to be conservative with regards to the magnitude of net migration and its impact in our population projections.

The third limitations emerges from the absence of demographic literature that deals with the Puerto Rico population dynamics apart from work from the late 90s, and early 2000s most of the literature was published between 1950 and 1990, which does not allow us to compare our result to other works. Despite these limitations, we understand that our paper presents the first analysis of its kind in the post-population decrease era.

FUTURE DIRECTIONS

An idea beyond the scope of our analysis is to develop a paper that considers an acceleration of the migration and a faster decline in fertility levels could add up to the literature and to the discussion of Puerto Rico's population prospects. A possible development of this method is to calculate a scenario in which migration accelerates (1.5 migration scenario), and immigration reduces gradually. Despite being an interesting postulate this seems like a work we need to ponder based on the current trends of the population of Puerto Rico. These trends will be consulted using the Puerto Rico Community Survey for another study.

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Appendix 1: Census information used for Figure 1

Year	Total Population	Population Growth Rate
1900	953,243	-
1910	1,118,012	17.29
1920	1,299,809	16.26
1930	1,543,913	18.78
1940	1,869,255	21.07
1950	2,210,703	18.27
1960	2,349,544	6.28
1970	2,712,033	15.43
1980	3,196,520	17.86
1990	3,522,037	10.18
2000	3,808,610	8.14
2010	3,725,789	-2.17

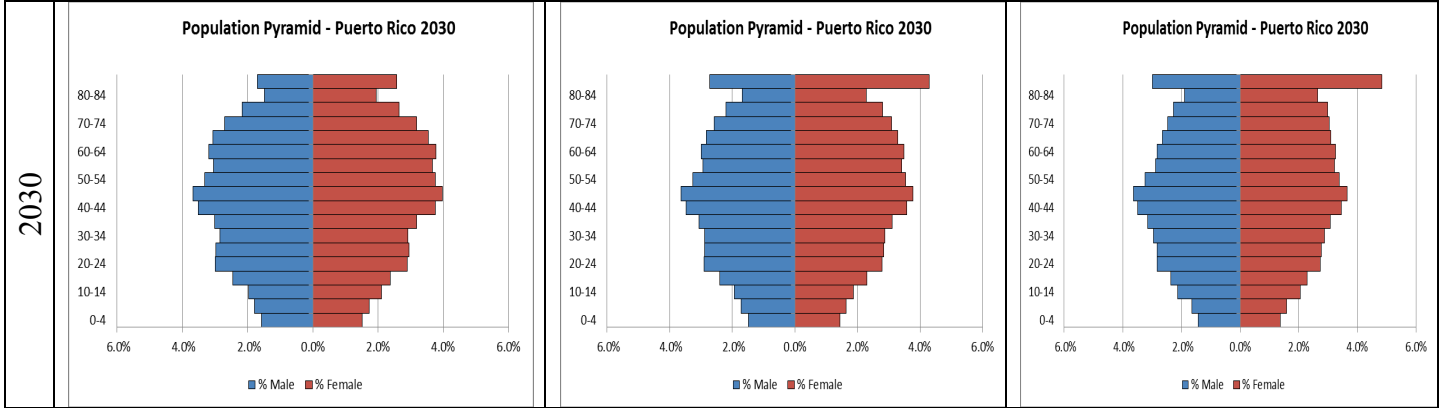
Appendix 2: Abridged Life Tables for Males and Females in Puerto Rico, 2010

Age	Male Population 2010	Male Deaths 2010	Mx	qx	Px	lx	dx	Lx	Tx	ex	Survival Rate
0	23,077	203	0.0088104	0.008772	0.991228	100,000	877	99386	7,538,440	75.38	0.993859738
1-4	92,096	16	0.0001740	0.000696	0.999304	99,123	69	396353	7,439,054	75.05	0.991478636
5-9	123,228	15	0.0001219	0.000609	0.999391	99,054	60	495118	7,042,701	71.10	0.998747399
10-14	137,289	18	0.0001313	0.000656	0.999344	98,993	65	494805	6,547,583	66.14	0.999367126
15-19	144,853	150	0.0010372	0.005172	0.994828	98,929	512	493363	6,052,778	61.18	0.99708637
20-24	130,577	347	0.0026539	0.013182	0.986818	98,417	1,297	488841	5,559,414	56.49	0.990833084
25-29	118,578	342	0.0028803	0.014298	0.985702	97,119	1,389	482126	5,070,573	52.21	0.986263425
30-34	119,708	317	0.0026523	0.013174	0.986826	95,731	1,261	475501	4,588,448	47.93	0.986259794
35-39	115,981	281	0.0024266	0.01206	0.98794	94,470	1,139	469500	4,112,947	43.54	0.987379362
40-44	114,941	361	0.0031370	0.015563	0.984437	93,330	1,452	463021	3,643,446	39.04	0.986199302
45-49	115,470	517	0.0044757	0.022131	0.977869	91,878	2,033	454306	3,180,426	34.62	0.98117893
50-54	110,600	714	0.0064568	0.031771	0.968229	89,845	2,854	442087	2,726,120	30.34	0.973102967
55-59	102,262	974	0.0095199	0.046493	0.953507	86,990	4,044	424839	2,284,033	26.26	0.960986781
60-64	100,090	1279	0.0127785	0.061915	0.938085	82,946	5,136	401889	1,859,194	22.41	0.945979604
65-69	80,178	1563	0.0194997	0.092967	0.907033	77,810	7,234	370966	1,457,304	18.73	0.923055292
70-74	61,731	1708	0.0276632	0.129369	0.870631	70,576	9,130	330056	1,086,338	15.39	0.889719455
75-79	43,625	1916	0.0439198	0.197873	0.802127	61,446	12,158	276834	756,282	12.31	0.838747862
80 +	50,887	5231	0.1028003	1	0	49,287	49,287	479449	479,449	9.73	0.633954731

Age	Female Population 2010	Female Deaths 2010	Mx	qx	Px	lx	dx	Lx	Tx	ex	Survival Rate
0	22,154	149	0.0067292	0.006707	0.993293	100,000	671	99531	8,324,321	83.24	0.995305
1-4	87,429	9	0.0001030	0.000412	0.999588	99,329	41	397236	8,224,791	82.80	0.993532
5-9	116,776	7	0.0000600	0.0003	0.9997	99,288	30	496368	7,827,555	78.84	0.999198
10-14	131,282	11	0.0000838	0.000419	0.999581	99,259	42	496189	7,331,188	73.86	0.999641
15-19	139,406	23	0.0001651	0.000825	0.999175	99,217	82	495881	6,834,998	68.89	0.999378
20-24	130,273	44	0.0003379	0.001688	0.998312	99,135	167	495258	6,339,118	63.94	0.998744
25-29	125,581	49	0.0003904	0.00195	0.99805	98,968	193	494357	5,843,860	59.05	0.998181
30-34	128,465	92	0.0007165	0.003576	0.996424	98,775	353	492991	5,349,503	54.16	0.997238
35-39	125,289	126	0.0010062	0.005018	0.994982	98,422	494	490873	4,856,512	49.34	0.995704
40-44	127,317	183	0.0014381	0.007165	0.992835	97,928	702	487884	4,365,639	44.58	0.993911
45-49	132,516	287	0.0021669	0.010776	0.989224	97,226	1,048	483511	3,877,754	39.88	0.991036
50-54	129,221	388	0.0030042	0.014909	0.985091	96,178	1,434	477307	3,394,243	35.29	0.987169
55-59	121,345	569	0.0046916	0.023186	0.976814	94,744	2,197	468230	2,916,937	30.79	0.980984
60-64	117,987	806	0.0068348	0.0336	0.9664	92,548	3,110	454964	2,448,706	26.46	0.971668
65-69	95,233	1018	0.0106847	0.052033	0.947967	89,438	4,654	435556	1,993,742	22.29	0.957341
70-74	74,520	1250	0.0167694	0.080473	0.919527	84,784	6,823	406864	1,558,186	18.38	0.934127
75-79	57,115	1662	0.0290969	0.135619	0.864381	77,961	10,573	363375	1,151,321	14.77	0.89311
80 +	78,709	6732	0.0855241	1	0	67,388	67,388	787947	787,947	11.69	0.684385

Appendix 3 Population Pyramids for Puerto Rico by Migration Scenario, 2015-2030

	Full Migration	Half Migration	Zero Migration
2015	<p>Population Pyramid - Puerto Rico 2015</p>	<p>Population Pyramid - Puerto Rico 2015</p>	<p>Population Pyramid - Puerto Rico 2015</p>
2020	<p>Population Pyramid - Puerto Rico 2020</p>	<p>Population Pyramid - Puerto Rico 2020</p>	<p>Population Pyramid - Puerto Rico 2020</p>
2025	<p>Population Pyramid - Puerto Rico 2025</p>	<p>Population Pyramid - Puerto Rico 2025</p>	<p>Population Pyramid - Puerto Rico 2025</p>



Appendix 4 Sex Specific Projections for Three Migration Scenarios

Puerto Rico Projection for 1 Migration Scenario for Male						
Age	2005	2010	2015	2020	2025	2030
0-4	109,083	106,261	87,697	70,341	60,719	51,834
5-9	111,512	105,615	103,788	84,909	68,105	58,789
10-14	117,261	106,112	100,633	98,762	80,798	64,807
15-19	137,202	117,187	106,112	100,570	98,700	80,746
20-24	144,431	136,802	117,187	105,803	100,276	98,412
25-29	127,086	140,570	134,399	114,054	102,974	97,596
30-34	107,531	115,246	129,404	121,878	103,428	93,381
35-39	114,676	103,011	111,986	123,965	116,755	99,081
40-44	114,832	113,541	103,291	110,877	122,738	115,599
45-49	112,934	112,828	113,126	101,488	108,941	120,595
50-54	115,633	113,094	115,111	113,285	101,631	109,095
55-59	108,728	113,676	114,222	113,162	111,368	99,911
60-64	96,079	102,155	111,238	107,316	106,321	104,635
65-69	94,909	91,106	102,385	105,480	101,761	100,817
70-74	70,214	83,114	86,794	89,662	92,372	89,115
75-79	47,355	53,862	72,924	66,581	68,780	70,860
80-84	30,846	33,484	46,770	51,563	47,078	48,633
85 +	27,196	31,020	58,084	56,038	57,506	55,894
Total	1,787,509	1,778,683	1,815,151	1,735,733	1,650,251	1,559,799

Puerto Rico Projection for .5 Migration Scenario for Male						
Age	2005	2010	2015	2020	2025	2030
0-4	109,083	106,812	88,929	71,627	61,762	52,852
5-9	112,852	106,884	105,570	87,137	70,183	60,517
10-14	120,167	110,049	104,363	102,948	84,972	68,440
15-19	137,202	120,091	110,049	104,297	102,882	84,918
20-24	144,431	136,802	120,091	109,728	103,993	102,583
25-29	128,233	141,838	135,601	117,936	107,758	102,127
30-34	112,240	121,379	136,205	128,353	111,632	101,999
35-39	116,370	109,110	119,662	132,407	124,774	108,519
40-44	114,675	115,059	109,258	118,314	130,916	123,368
45-49	113,145	112,883	114,849	107,551	116,465	128,870
50-54	114,465	112,160	114,025	113,849	106,614	115,451
55-59	108,177	111,957	112,719	111,526	111,355	104,278
60-64	97,176	102,796	110,756	107,113	105,979	105,816
65-69	94,796	92,036	102,912	104,898	101,447	100,374
70-74	72,112	85,259	89,858	92,559	94,345	91,241
75-79	51,139	59,738	80,032	74,440	76,677	78,157
80-84	33,718	39,526	55,806	61,858	57,536	59,265
85 +	32,260	41,827	81,353	86,953	94,339	96,282
Total	1,812,239	1,826,207	1,892,038	1,833,492	1,763,630	1,685,056

Puerto Rico Projection for Zero Migration Scenario for Male						
Age	2005	2010	2015	2020	2025	2030
0-4	109,083	107,364	90,167	80,939	62,812	53,888
5-9	114,192	108,153	107,364	89,398	80,250	62,276
10-14	123,074	114,049	108,153	107,230	89,286	80,149
15-19	137,202	122,996	114,049	108,085	107,162	89,230
20-24	144,431	136,802	122,996	113,716	107,770	106,850
25-29	129,380	143,107	136,802	121,868	112,674	106,782
30-34	116,949	127,603	143,107	134,923	120,194	111,126
35-39	118,063	115,342	127,603	141,141	133,069	118,543
40-44	114,517	116,573	115,342	125,992	139,359	131,390
45-49	113,355	112,937	116,573	113,750	124,254	137,436
50-54	113,297	111,221	112,937	114,379	111,610	121,915
55-59	107,625	110,249	111,221	109,899	111,303	108,608
60-64	98,272	103,426	110,249	106,882	105,612	106,960
65-69	94,683	92,964	103,426	104,294	101,108	99,906
70-74	74,009	87,398	92,964	95,468	96,269	93,329
75-79	54,923	65,847	87,398	82,712	84,940	85,652
80-84	36,590	46,067	65,847	73,305	69,374	71,243
85 +	32,260	43,648	89,715	98,619	108,992	113,076
Total	1,831,905	1,865,746	1,955,913	1,922,601	1,866,036	1,798,359

Puerto Rico Projection for 1 Migration Scenario for Female						
Age	2005	2010	2015	2020	2025	2030
0-4	104,958	102,242	84,258	75,113	58,421	49,876
5-9	106,332	101,843	99,870	81,758	72,884	56,688
10-14	111,255	101,305	97,110	95,148	77,893	69,438
15-19	131,235	111,215	101,305	97,075	95,114	77,865
20-24	139,319	131,153	111,215	101,242	97,015	95,055
25-29	129,813	138,828	130,855	110,823	100,884	96,672
30-34	119,400	123,424	132,248	124,415	105,368	95,919
35-39	127,625	118,620	122,958	131,383	123,601	104,680
40-44	125,138	127,471	118,986	122,810	131,225	123,453
45-49	126,792	124,622	127,722	118,496	122,304	130,684
50-54	133,955	128,169	127,092	129,109	119,783	123,632
55-59	130,172	134,941	130,757	128,028	130,059	120,664
60-64	115,815	124,240	131,357	124,798	122,193	124,132
65-69	112,235	110,168	121,702	124,953	118,713	116,236
70-74	83,910	98,890	101,769	107,232	110,096	104,598
75-79	58,827	66,240	84,579	80,338	84,651	86,911
80-84	43,214	44,510	57,199	63,995	60,785	64,048
85 +	45,635	51,514	85,981	83,015	85,235	84,662
Total	1,945,630	1,939,395	1,966,964	1,899,729	1,816,225	1,725,213

Puerto Rico Projection for .5 Migration Scenario for Female						
Age	2005	2010	2015	2020	2025	2030
0-4	104,958	102,773	85,442	68,918	59,426	50,853
5-9	107,603	103,061	101,581	83,898	67,673	58,352
10-14	113,969	105,016	100,666	99,139	81,881	66,046
15-19	131,235	113,928	105,016	100,630	99,103	81,851
20-24	139,319	131,153	113,928	104,951	100,567	99,041
25-29	129,961	138,986	131,004	113,655	104,700	100,327
30-34	122,377	126,645	135,692	127,661	110,755	102,028
35-39	127,868	121,807	126,406	135,061	127,068	110,240
40-44	124,944	127,516	121,996	126,058	134,690	126,718
45-49	126,667	124,307	127,641	121,373	125,415	134,002
50-54	132,641	126,787	125,538	127,762	121,488	125,533
55-59	128,868	132,279	128,067	125,195	127,413	121,155
60-64	117,426	124,706	130,522	123,931	121,152	123,298
65-69	113,439	112,900	123,432	125,491	119,154	116,482
70-74	87,540	104,276	108,596	113,462	115,354	109,529
75-79	64,219	75,440	96,731	93,585	97,778	99,409
80-84	47,112	52,972	70,291	79,790	77,195	80,654
85 +	53,867	69,109	122,081	131,657	144,711	151,869
Total	1,974,013	1,993,660	2,054,631	2,002,217	1,935,522	1,857,389

Puerto Rico Projection for Zero Migration Scenario for Female						
Age	2005	2010	2015	2020	2025	2030
0-4	104,958	103,304	86,631	77,878	60,436	51,850
5-9	108,874	104,279	103,304	86,070	77,375	60,045
10-14	116,682	108,787	104,279	103,221	86,001	77,312
15-19	131,235	116,640	108,787	104,241	103,184	85,970
20-24	139,319	131,153	116,640	108,719	104,176	103,120
25-29	130,109	139,144	131,153	116,494	108,583	104,046
30-34	125,353	129,873	139,144	130,915	116,282	108,385
35-39	128,110	125,006	129,873	138,760	130,553	115,961
40-44	124,751	127,560	125,006	129,315	138,164	129,992
45-49	126,542	123,991	127,560	124,245	128,527	137,323
50-54	131,328	125,407	123,991	126,416	123,131	127,375
55-59	127,563	129,643	125,407	122,400	124,794	121,551
60-64	119,037	125,137	129,643	123,023	120,073	122,421
65-69	114,644	115,665	125,137	125,970	119,537	116,671
70-74	91,170	109,754	115,665	119,799	120,596	114,438
75-79	69,611	85,165	109,754	108,046	111,907	112,652
80-84	51,010	62,170	85,165	98,022	96,497	99,946
85 +	53,867	71,776	133,947	149,957	169,713	182,190
Total	1,994,164	2,034,455	2,121,085	2,093,491	2,039,529	1,971,247

Endnotes

ⁱ The opinions or assertions contained herein are the private views of the authors and are not to be constructed as official or as reflecting the views of the institutions they are affiliated with.

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ⁱⁱⁱ Calculations were performed using 2000 and 2010 US Census population structures. Births and deaths for the period were adjusted to avoid double accounting of events and to reflect population for April 2010.