

## **Population of Puerto Rico not displaced by Hurricanes (for now): It's the economy**

### **Abstract**

In September 2017, Hurricane Maria made landfall on Puerto Rico and caused 102 billion worth of damages, demolishing the electric grid and severely affecting essential daily services that continued as of the second half of 2019. Amidst the chaos, analysts were expected to provide stakeholders with impact estimates immediately following the hurricane. Unfortunately, this strong need for fast information after the disaster coincided with limited options for high-quality data sources to help stakeholders address challenges such as resource allocation and bond-pricing. Given the stabilization of data sources since the hurricanes, this paper examines historical demographic and economic data to give a long-term view of population change in Puerto Rico. First, we juxtapose population, employment, hurricanes and significant economic events to make the argument that the clearest driver of population decline in Puerto Rico is simply the economic health of the island (i.e. employment). Second, we focus on Pre- and Post-Hurricane Irma/Maria migration estimates to highlight the spike in outmigration following the hurricanes, as well as the, return immigration in the first half of the first half of 2018. Finally, we study historical net outmigration and employment trends to illustrate the short-lived outmigration impacts of hurricanes while also highlighting the long-term outmigration impacts of economic downturns. In short, we argue that the primary reason people are leaving Puerto Rico is the struggling economy and not hurricane-related destruction. The hurricanes simply exacerbated the economic-related outmigration trends and we believe that any serious plans for Puerto Rico's restoration must include special attention to stimulate the economy.

**Keywords:** Population Change, Migration, Hurricane Maria, Puerto Rico, Demography of Disaster, Employment

## Introduction

Hurricane Maria has raised many questions about the future of Puerto Rico's population. As social scientists we are aware that individual and collective decisions are influenced by rational analyses of socioeconomic and environmental risks (Bardsley & Hugo, 2010). Unfortunately, recent analyses of population change in Puerto Rico tend to overstate the demographic impact of Hurricane Maria for three reasons (Meléndez & Hinojosa, 2017; Stone, 2017a, 2017b). First, timing constraints forces analysts to use return net air passenger traffic data to estimate migration prior to the completion of hurricane-related return migration; and incorporating this downward shift into the future. Second, the two highest quality data sources to estimate Puerto Rico outmigration, provided by the Bureau of Transportation Statistics (BTS) and the Puerto Rico Community Survey (PRCS), have limitations in unknown coverage and bias. The collection of the latter was interrupted by the Hurricane and estimates were produced using data from the pre-Hurricane period. Third, existing outmigration due to the economy is typically included in "hurricane-related outmigration" estimates. After reviewing hurricane-related outmigration report, we argue that Hurricanes Irma and Maria served as a brief catalyst for outmigration from Puerto Rico, but the main driving force was (and continues) economic instability.

In order to grasp the value of BTS air traffic data as an estimate for migration, analysts must consider spikes in both outbound net air traffic immediately following hurricanes and inbound net air traffic following restoration of power and basic infrastructure. Considering the minimal travel restrictions between Puerto Rico and the continental United States (US), analysts may have incorrectly underestimated the rate at which Puerto Ricans seeking temporary refuge in the US would ultimately return to Puerto Rico. Publishing post-natural disaster estimates with inadequate data sources and unverified assumptions violates the growing list of "best practices" suggested by the "demography of disaster" literature (S. K. Smith & McCarty, 1996). For better or for worse, such forecasts have been used by the Government of Puerto Rico and the Financial Oversight and Management Board of Puerto Rico to frame discussions and make conclusions about the economic prospects of the island (Government of Puerto Rico, 2018; Stone, 2017a).

It is imperative that demographers and those employing demographic techniques to approach our projects with caution and to fully discuss all the assumptions behind our models (Wang, Cai, Shen, & Gietel-Basten, 2018). Centers that specialize in the production of

demographic products have approached the production of estimates and projections post-Hurricane Maria with caution by highlighting the number of assumptions involved in their calculations (Meléndez & Hinojosa, 2017; Rayer, 2018). Additionally, researchers should keep in mind that estimates, projections, and forecasts are employed in decision-making processes which can impact business decisions and the distribution of federal funds (S. K. Smith, 1996).

Demographic research without serious consideration for these principles may lead to the perils of “*spreadsheet demography*” (Wang et al., 2018). Wang and colleagues (2018) characterize “*spreadsheet demography*” as exercises that are 1) undertaken without any consideration of the empirical or sociological meaning, 2) the lack of critical self-reflection, and 3) those that prioritize the population over the people. Practitioners of population projections and forecasts should educate decision-makers about the limitations of their products and the uncertainty inherent with each one (Wang et al., 2018). The production of projections or forecasts without these considerations could seriously harm the future of the area(s) being analyzed by misinforming decision-making processes.

Our analysis contributes to this growing body of literature by presenting an analysis of total population, employment, and net migration trends in Puerto Rico pre- and post-Hurricane Maria. Also included is an analysis that considers major environmental and economic events that have affected Puerto Rico since 1990 and how they have shaped its current population.

## **Background Literature**

On January 1990, Puerto Rico entered a new decade recovering from the devastating effects of Hurricane Hugo. Though the eye of the Hurricane did not pass through the island it caused significant devastation for the population and the environment (National Research Council, 1994; Philen et al., 1992). By that point, the economy of Puerto Rico had transformed from mainly agricultural into a manufacturing or labor intensive one (Curet Cuevas, 2003). The manufacturing sector, comprised mostly of US-owned factories attracted by tax breaks and low-wages, provided the majority of the jobs for the population of Puerto Rico until 1995 (Feliciano, 2018). In turn, the government subsidized and invested heavily in providing infrastructure necessary for the success of these business endeavors (Caraballo-Cueto & Lara, 2017). However, the vitality of this sector depended largely on IRS Tax Section 936, which provided the tax-exemptions to international companies (Feliciano, 2018; Feliciano & Green, 2017). By the end of the decade, the population of Puerto Rico had increased from 3,522,037 to 3,808,610 (U.S.

Census Bureau, 2000, 2010) - an increase of 8.14%, even though two major hurricanes ravaged the island (hurricanes Hortense and Georges). In fact, the preceding decade had witnessed two tropical storms and Hurricane Hugo affecting Puerto Rico and the population grew by 10.10%.

The tax breaks granted under Section 936 brought about the attention of many who argued that this statute eroded the tax base for the US (Caraballo-Cueto & Lara, 2017). These critiques, paired with the incorporation of the US in the World Trade Organization, bought about a 10-year plan for phasing out the tax-credits by December 2005. Under the phase-out plan, effects from eliminating the tax-credit would not be felt until the mid-2000s (Lloréns, 2018). Most discussions about the tax-repeal centered on economic dynamics and employment, but no study foresaw how the island's economic instability would affect the population. Both the Puerto Rico Planning Board and the US Census Bureau produced estimates for the 2000-2010 period that placed the population close to 4 million by 2010 (Santos-Lozada & Velazquez-Estrada, 2015). During the mid-2000s, the economy of Puerto Rico started giving clear signs of deterioration with a budgetary crisis that resulted in the first shutdown of the government of Puerto Rico and the imposition of a 7% sales tax. By 2008, the global Great Recession was well on its way and served as additional - *yet short-lived* - headwind holding back Puerto Rico's economic growth. That year, an official publication of the Federal Reserve Bank of New York included a comment about "Puerto Rico's population[reaching] nearly 3.9 million" (Bram, Martínez, & Steindel, 2008). This publication discussed the two-year-long economic downturn and population dynamics in relation to economic activity in the past, but did not address the ramifications from the expiring Section 936 tax-exemptions. Adding to the comment by Caraballo-Cueto and Lara (2017) that, "*It is far from a coincidence that Puerto Rico's current economic depression began in 2006, the last year in the phase-out of Section 936*", it is also not coincidental that the first recorded population decline occurred a few months before these credits expired. While the economy started to weaken, few anticipated the underlying population decline prior to the publication of the 2010 Decennial Census results.

The results of the 2010 Decennial Census indicated that the population had decreased from 3,808,610 to 3,725,789 persons, a percent change of -2.17% (U.S. Census Bureau, 2010). An examination by Santos-Lozada and Velazquez-Estrada (2015) of the main demographic indicators pointed to outward migration as the driving force behind the population decline because the natural growth (balance between births and deaths) remained positive for this period

(see Table 1). In fact, revised inter-censal population estimates from the U.S. Census Bureau indicate that the onset of the population decline was in 2005 (U.S. Census Bureau, 2012). A noteworthy contrast between the more recent period of population decline and the historical years of population growth is that the population contracted without a major hurricane between 2000 and 2010, and expanded the previous decade despite two major hurricanes, Hortense and Georges. For the 2000-2010 period, on the other hand, the population of Puerto Rico declined even though it was not affected by any major environmental event. The Puerto Rico Institute of Statistics indicated that the net passenger flow for the island has been negative for every year of the decade (Velazquez-Estrada, Marazzi-Santiago, Orenstein-Cardona, & Romero-Pagán, 2018). By the mid-2010s, Puerto Rico's economic situation declined further when it was not able to repay government bonds fully in the municipal bond market (Caraballo-Cueto & Lara, 2017; Rodríguez-Díaz, 2018). Adding everything up, the island was experiencing population decline and a deteriorating economic situation prior to Hurricane Maria. The population decline stemmed from outmigration and negative natural growth (deaths outnumbering births in 2015), while the deteriorating economic situation was due to the lack of jobs, expiring tax-exemptions, and most recently the appointment of the Financial Oversight and Management Board (Rodríguez-Díaz, 2018). Matters go even worse for Puerto Rico, when the island encountered Hurricanes Irma and Maria in 2017.

Table 1. Natural Increase and Net Migration for Puerto Rico 2000-2010								
		Natural Increase			Net Migration			Growth
Year		Births	Deaths	Natural Increase (NI)	Inward Passengers	Outbound Passengers	Net Passenger (NP)	(NI) + (NP)
1990-1994		325,119	136,833	188,286	22,428,511	22,571,101	-142,590	45,696
1995-1999		311,193	148,297	162,896	24,556,147	24,705,000	-148,853	14,043
2000-2004		270,356	145,141	125,215	25,128,906	25,260,745	-131,839	-6,624
2005-2009		236,676	146,161	90,515	26,145,426	26,367,699	-222,273	-131,758
Sources: Puerto Rico Vital Statistics System (1990-2009) and BTS (1990-2005).								

In July 2017, Puerto Rico had an estimated population of 3,325,001 people. This represented a decline of 81,494 or 2.39% from the estimate for the same month in 2016 (U.S.

Census Bureau, 2018). Hurricanes Irma and Maria made landfall in Puerto Rico in September 2017 (Zorrilla, 2017). These hurricanes caused the collapse of the electricity grid and the healthcare system, and politicians and private entrepreneurs turned to the government for rescue due to the devastation caused on the island (Alcorn, 2017; Lugo, 2019; Shultz & Galea, 2017). Following the hurricane, impact discussions circled around mortality and migration. The discussion of post-disaster mortality has been the subjects of many studies and received worldwide attention (Sandberg et al., 2019; Santos-Lozada & Howard, 2018) as the majority of Hurricane-related deaths occurred in the aftermath of Hurricane Maria (Rivera & Rolke, 2019). Others were concerned about the displacement of Puerto Ricans, which could weaken tax revenues and other economic indicators further. During this tumultuous period, numerous studies used sound statistical methodologies to estimate post-hurricane displacement while cautiously stating that their observed trends may not continue long-term (Hinojosa, Román, & Meléndez, 2018; Meléndez & Hinojosa, 2017). In contrast, other studies performed immediately following the hurricanes attempted to forecast post-disaster dynamics far into the future with limited data. Ultimately, studies performed too quickly after the hurricanes appear to have overstated the magnitude of hurricane-induced population displacement and likely misinformed policy decision-makers (Stone, 2017a, 2017b). In a similar manner, the study used to certify the number of deaths did not incorporate return migration for January and February 2019 which resulted in an overestimation of approximately 1,000 deaths (Rivera & Rolke, 2019; Santos-Burgoa et al., 2018). These two examples demonstrate that impact estimates produced immediately following natural disasters are employed in processes with implications to the people. In addition, they are subject to extra scrutiny given that quality data is not available to any researcher when a community is disrupted.

The objective of this study is to describe how major environmental and economic events have impacted the population, employment and net migration trends in Puerto Rico. To start, we discuss trends in total population and employment for the period, noting the strong relationship between employment and population growth. Then we study pre- and post-Hurricane Maria net migration patterns, noting the dramatic shifts from outmigration to return migration after hurricane Maria in the first months of 2019. Finally, we discuss trends in net migration and employment to emphasize historical outmigration trends in context with hurricanes and employment. We believe this background is absent from current scholarship and is an essential

component of any defensible population of economic forecast of Puerto Rico and can guide future analyses on this topics.

## Data and Methods

As there are no official measures for migration flows, we rely on air passenger traffic data as a proxy for net migration (Melendez, 1994)<sup>1</sup>. In specific, air passenger traffic data from the US Bureau of Transportation Statistics are used to indirectly gauge net migration flows out of Puerto Rico. We include passengers entering and leaving Puerto Rico as their final destination (U.S. Bureau of Transportation Statistics, 2018). Although these “*net migration*” calculations includes tourists, they effectively become zero following their stints to/from Puerto Rico. Most of the air travel in and out of Puerto Rico is on domestic flights between Puerto Rico and the continental US. As such, we use net domestic passenger flow to obtain more timely estimates through November 2018<sup>2</sup>. The 12-month net domestic outflow sums the net outflow from the previous 12-months, which eliminates sources of bias such as random noise and temporal travel (J. Smith & Sharfman, 2007). Next, we establish historical ranges of variation for 2010-2016 using the minimums and maximums over the overlapping months as used by previous estimates of post-hurricane Maria migration (Meléndez & Hinojosa, 2017).

For employment, we use totals from the Employed, Non-Agriculture, Seasonally Adjusted data series (Bureau of Labor Statistics, 2018). For total population estimates, we use data produced by the Puerto Rico Planning Board for 1990-2000 and the Population Estimates Program for the 2000-2018 period (Puerto Rico Planning Board, 2004; U.S. Census Bureau, 2018). Finally, we identified major hurricanes from 1989 onward that made at least partial landfall in Puerto Rico, as well as major economic events. Altogether, these data allow us to study the relations between hurricanes, economic events, total population, employment, and net migration. Following the Saffir-Simpson Hurricane Scale, we only include hurricanes reaching Category 3 or higher as major hurricanes because these hurricanes had the potential for significant loss of life and damage (Zhai & Jiang, 2014). Under this operationalization, we

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<sup>1</sup> While migration via land is impossible in the case of Puerto Rico it is possible over sea, in both registered and unregistered boats.

<sup>2</sup> The BTS publishes international flight data with an additional 3-month lag. While we could have chosen this route, we did not want to leave out from our analysis the possibility that Hurricane Maria impacted Puerto Rico’s net migration between September and November 2018.

identified five Hurricanes: 1. Hurricane Hugo (Category 3-4, September 1989), 2. Hurricane Hortense (Category 1 on landfall in Puerto Rico, reached Category 4 days later, September 1996), 3. Hurricane Georges (Category 4, September 1998), 4. Hurricane Irma (Category 5, September 2017), and 5. Hurricane Maria (Category 5, September 2017). We included three major economic events in our analysis: 1. the onset of the 2006 Puerto Rico budget crisis (May 2006), which led to the first and only Puerto Rico government shutdown, 2. the onset of the global Great Recession (December 2007), and 3. the onset of the Puerto Rico debt crisis (February 2014). In Figures 1 and 3, we flag these as “*major events*” to highlight their timing in relation to changes in total population, net migration, and employment.

## Results

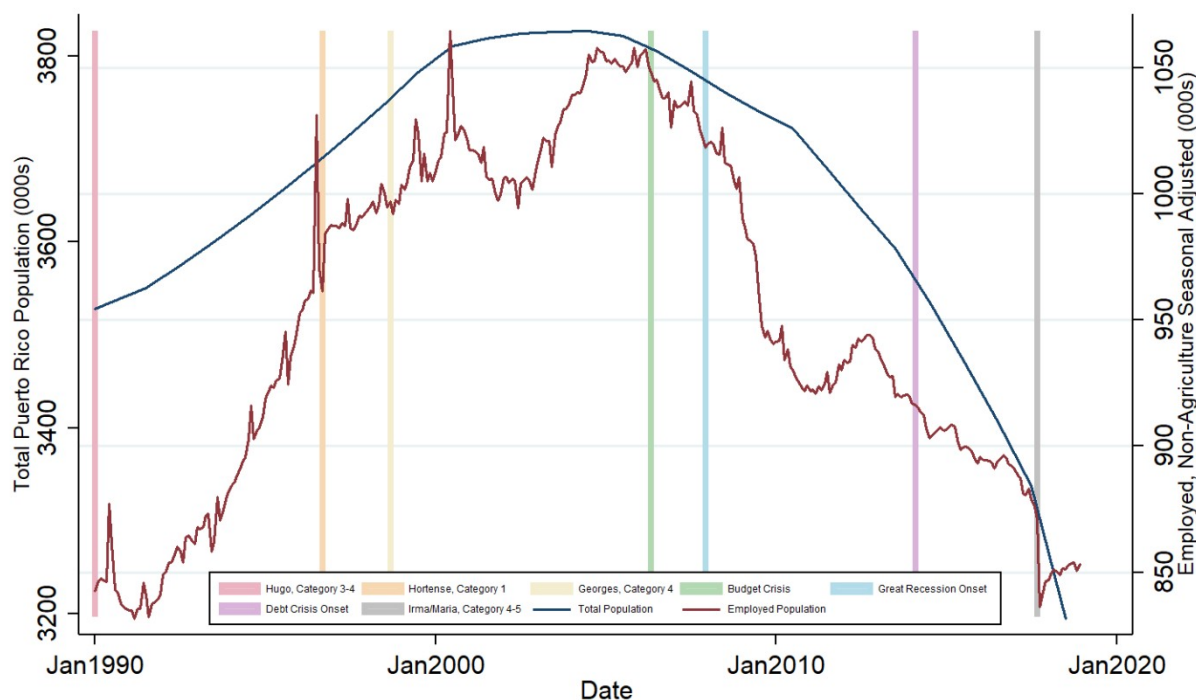
In Figure 1, we present historical trends for total population and non-agricultural employment in Puerto Rico, as well as major events that occurred during our period of analysis. We identify four time-windows of interest: (1) pre-budget crisis (1990-April 2006), (2) post-budget crisis and debt-crisis onset (May 2006-January 2014), (3) debt-crisis pre-Hurricane Maria (February 2014-August 2017), and (4) post-Maria (September 2017 onward). We must note that the onset of the debt-crisis does not mean a budgetary crisis did not exist; the 2006 budget crisis was particularly noteworthy as it marked the first local government shutdown ever experienced in Puerto Rico.

In the first period, Hurricanes Hortense and Georges made landfall in Puerto Rico. Even though two hurricanes hit Puerto Rico, we observe an increase in population (blue line, left y-axis) and employment (red line, right y-axis) that sustained until the onset of the budgetary crisis of 2006. The budget crisis also coincided with the end of the 10-year phase out period for the expiration of Section 936 of the US Internal Revenue Code, which granted tax exemptions to non-local companies with manufacturing operations on the island. This 10-year phase-out period was enacted by Congress in 1995 and finished by the end of 2005 (U.S. General Accounting Office, 1997). Following the expiration of these tax exemptions, manufacturing employment decline, as did overall employment and eventually population. Based on this analysis, the displacement of Puerto Rico’s population is likely due to employment and economic factors, rather than hurricanes.

In order to examine the hypothesis that hurricane-induced displacement is the principal cause of population decline, we analyze whether pre-Hurricane Maria patterns were consistent



with historical ranges of variation and whether this changed following September 2017. In Figure 2, we present Net Domestic Air Passenger Outflow and establish ranges of variation by month by shading the minimum and maximums over the previous 6-7 years (gray)<sup>3</sup>. Post-hurricane Maria data for July through November 2018 (green line) is consistent with pre-Maria seasonal migration patterns observed for the period July 2010 through June 2017. The red line presents Net Air Domestic Passenger Outflow of Puerto Rico for the 2017-2018 Hurricane Season, in which Hurricane Maria impacted Puerto Rico. The outward displacement peaks at almost 100 thousand passengers leaving Puerto Rico on net in October 2017. The return migration peaks at about 70 thousand passengers arriving in Puerto Rico on net in January 2018, which is followed by lower-than-normal net outflow through May 2018. By the summer of 2018, migration patterns based on net air traffic returned to pre-hurricane levels.

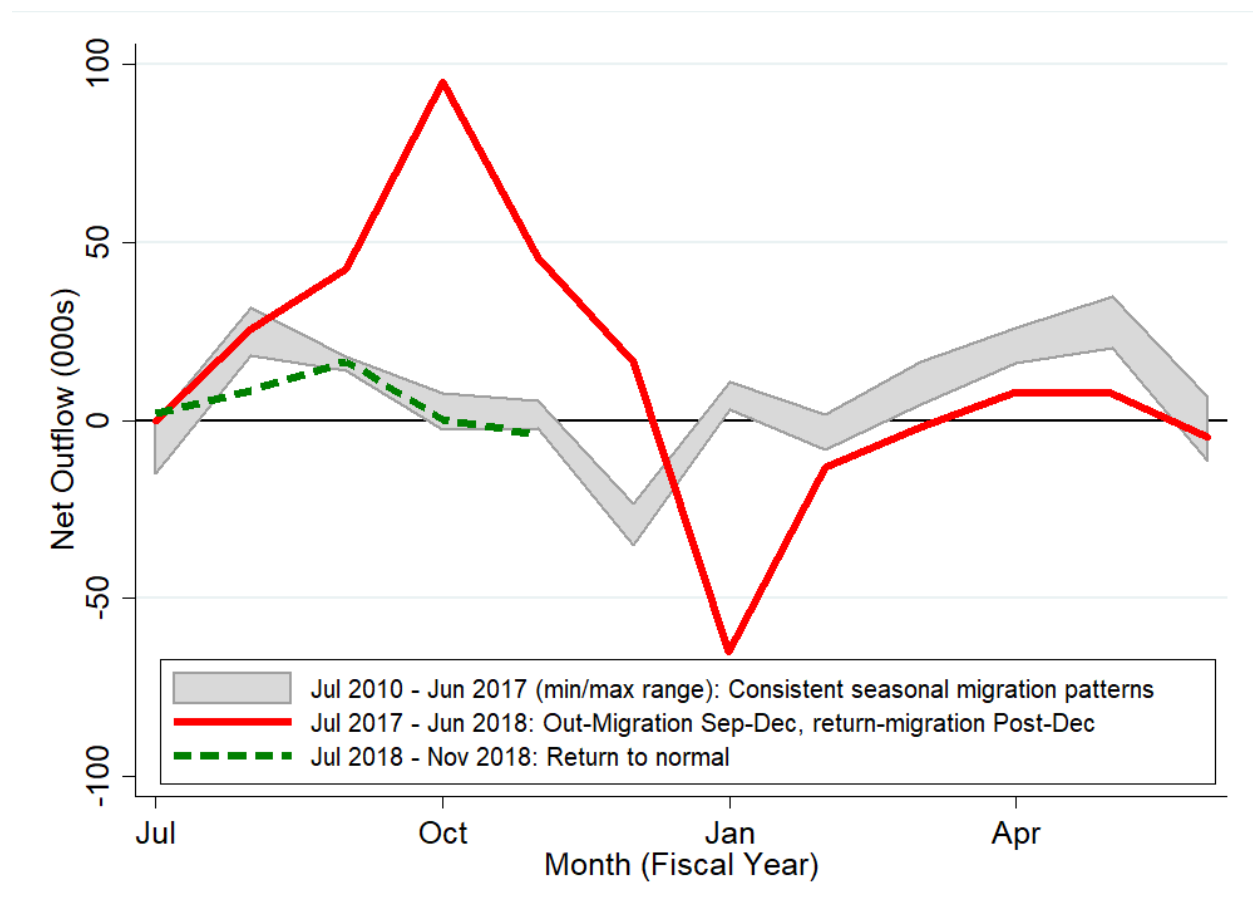


**Fig 1.** Population and employment from 1990 – 2018. The blue line traces the population change, while the red line the employment population (non-agriculture, seasonally adjusted). The vertical lines illustrate major climatic and economic events on the island, including (left-to-right) Hurricane Hugo (red), Hurricane Hortense (orange) Hurricane Georges (gold), the 2006 Budget

<sup>3</sup> We present the monthly data from July through June, instead of from January through December, because it allows us to display the effects of the yearly Atlantic basin Hurricane season, which affects Puerto Rico starting in the summer month of July over the following 12 months.

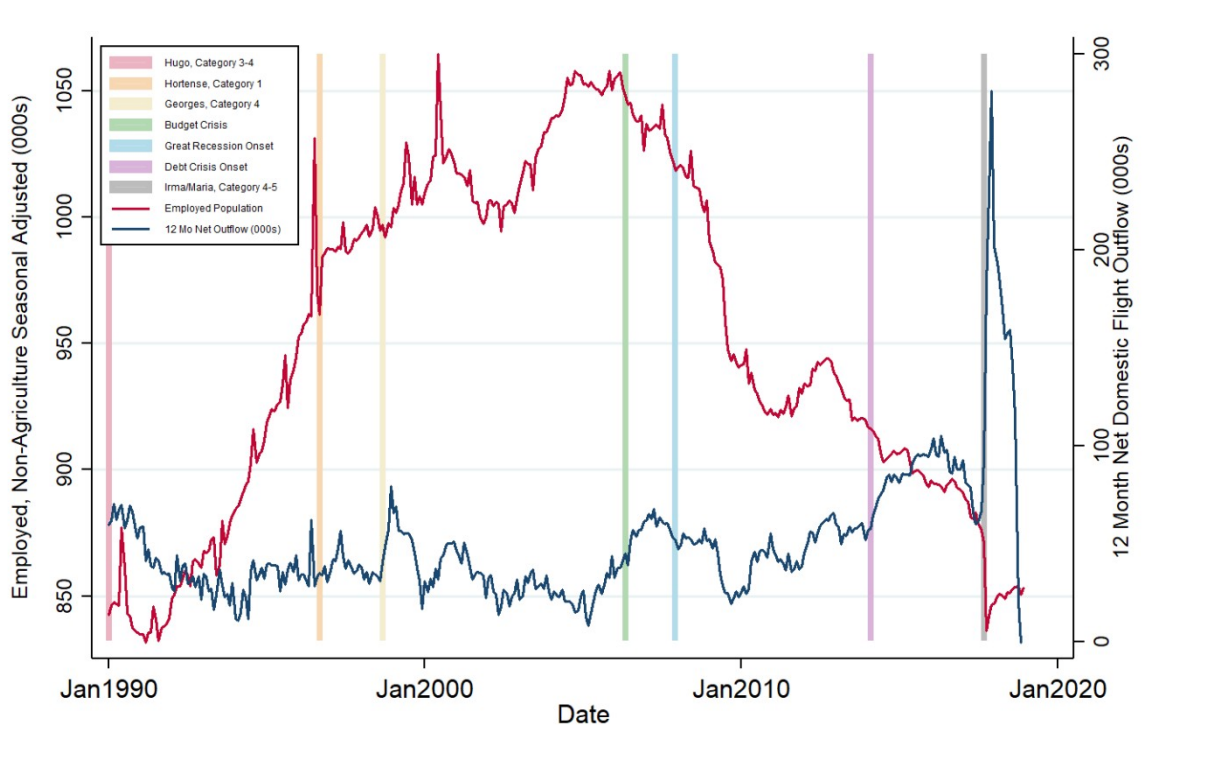
Crisis (green), the onset of the Great Recession (blue), the onset of the Debt Crisis (purple) and Hurricanes Irma and Maria (gray).

Based on these results, the 2018 Hurricane season did displace some of Puerto Rico's population, but displacement was temporary for most of the affected population. On the other hand, the long-term negative effects of a struggling economy have undoubtedly influenced migration trends pre- and post-Maria. This is not to say the hurricanes had no effect on outmigration; rather that the initial drive to leave the island tapered off (and reversed for many people) after the island regained power and basic infrastructure that was compromised by the hurricanes.



**Fig 2.** Net Air Domestic Passenger Flight Outflow (a proxy for Out-Migration) for the 2010 decade. The 2010 – 2016 gray shaded area represents the min/max range of the period. The red line illustrates the Out-Migration pattern for 2017 (the year of the hurricanes), and the green dotted line 2018. The years represent *fiscal years* from July – June, which also better coincides with the hurricane season than the calendar year.

Having established that post-Maria migration dynamics, aside from the shock from this event, were consistent with those of the previous years (2010-2016) we look for historical examples of migration during the period of a major hurricane. Figure 3 shows patterns of passenger outflow and employment, along with relevant environmental and economic shocks to the economy of Puerto Rico. Here the drive of post-Maria outmigration estimates are clearly illustrated: outmigration spikes following Hurricanes (particularly following Hurricanes Irma and Maria). However, for all hurricanes, we see that this spike in outmigration is short-lived and followed by months of relatively lower outmigration. Note how the blue line below climbs then following the hurricanes (shaded red, orange, gold, and grey vertical lines). Migration patterns changed dramatically the months immediately following Hurricanes Irma and Maria by climbing suddenly (out-migrants seeking shelter in the mainland) and dropping (return migrants), which can also be seen on a smaller scale around the time of Hurricanes Hugo and Georges.



**Fig 3.** 12-Month Net Domestic Passenger Flight Outflow (a proxy for Annualized Out-Migration) and employment from 1990 – 2018. The blue line traces the change in annualized out-migration, while the red line the employment population (non-agriculture, seasonally adjusted). The vertical lines illustrate major climatic and economic events on the island, including (left-to-right) Hurricane Hugo (red), Hurricane Hortense (orange) Hurricane Georges (gold), the 2006 Budget Crisis (green), the onset of the Great Recession (blue), the onset of the Debt Crisis (purple) and Hurricanes Irma and Maria (gray).

Although migration changes are short-lived following hurricanes, we see a much stronger pattern occurring in the background. Namely, as employment increases (an indicator for economic health - red line above), outmigration declines remain stable or even reverse slightly for non-hurricane periods. However, post-2000 population growth was slower than in the previous decades coinciding with the first fall in employment. Overall, as employment began to plummet following the budget crisis of 2006 (green vertical shaded line above), one sees how the pattern of migration fundamentally changed by climbing upward. Outmigration seemed to subside as the global Great Recession matured (light blue vertical line), but then a steady climb ensued, especially following the Debt Crisis of 2014 (purple vertical line). Again, this gives further evidence to the role that economic factors play in determining the evolution of migration flows. These factors eclipse the short-lived effect that hurricanes Irma and Maria have played.

## **Discussion**

Throughout the 20<sup>th</sup> century, Puerto Rico grew continuously. The implementation of basic public health programs in the early 20<sup>th</sup> century reduced the high infant and overall mortality rates that plagued the island initially (Janer, 1945). In recognition of the need to support economic development on the island, the US government's policy towards Puerto Rico has included the use of tax incentives to attract investment to the island since 1921 (U.S. General Accounting Office, 1993). For 85 years, this policy generated an illusion of economic prosperity as US corporations invested significant amounts in developing their operations on the island. In the process, the people of Puerto Rico benefited from this steady source of income and employment, which served as the foundation for the development of the island, and the transition from an agricultural economy to a modern industrial (Curet Cuevas, 2003).

Between 1945 and 1960, the Great Puerto Rican exodus took place, during which an estimated half a million Puerto Ricans migrated to the US. Despite the Great Exodus, Puerto Rico's population continued to grow, due to high fertility rates on the island. Between 1970 and 2000, the Total Fertility Rate (TFR) for Puerto Rico declined from 3 to 1.2 children per woman in 2016 (Morales-González, 2019; Warren, 1987) setting the stage for a dramatic demographic turnaround at the turn of the 21<sup>st</sup> century.

In 2005, Puerto Rico's population officially began to decline, initially due to outmigration and most recently by the fall of the TFR to below replacement levels (Abel & Dietz, 2014; Mora, Dávila, & Rodríguez, 2017). Until 2016, Puerto Rico had positive natural

increase, but vital records show deaths outnumbering births in every year also for 2017 and 2018. Population decline since 2005 coincides with depressed employment (as well as a slowdown in the GDP growth, see Supplemental Materials), the 2006 budget crisis, and the expiring tax-exemptions granted under Section 936 of the US Internal Revenue Code (Caraballo-Cueto & Lara, 2017). Additionally, the downward population trend accelerated following the 2014 debt crisis. In other words, the primary stimulus of Puerto Rico's population decline is the declining health of the economy, which is not likely to make great strides going forward if federal funding for disaster recovery is insufficient. Indeed, evidence suggests that post-disaster aid has been insufficient and lower than for other jurisdictions stricken by comparable disasters in the same year in Texas and Florida (Willison, Singer, Creary, & Greer, 2019).

By July 2018, and estimated 150,000 net air passengers had returned to Puerto Rico since leaving the island following Hurricanes Irma and Maria. The rush to produce post-Maria projections two months after a natural disasters means that the returning air traffic, which occurred in 2018 was not incorporated in the population forecasts produced in November 2017 (Stone, 2017a). Neglecting to wait for quality data or thoroughly evaluating all possible data sources reflects poor professional judgement when comparing these actions against prior "*demography of disaster*" studies. For example, after Hurricane Katrina devastated New Orleans data from public school enrollment, utility companies, the US postal service, the Federal Emergency Management Agency, and homeowner's insurance agencies were used to understand population change (Hori, Schafer, & Bowman, 2009). After Hurricane Andrew, population change attributed directly to the hurricane subsided within approximately two years (S. K. Smith & McCarty, 1996). Additionally, Smith and McCarty (1996) reviewed Red Cross reports, insurance records, property appraisal files, postal change-of-address requests, utility company records, and Census Bureau data in the aftermath of Hurricane Andrew in Florida. They ultimately concluded that these data "provide valuable information, but none of these provides timely and comprehensive data on housing damages and population movements, for small geographic areas, or for multiple points in time." To address these data quality challenges, Smith and McCarthy (1996) indicated that the only way to collect the necessary data was through a series of sample surveys. With regards to Puerto Rico, some researchers have analyzed alternative data sources to understand migration (Hinojosa et al., 2018) and also fielded a survey

approximately 6,000 households in the US to collect information about the situation in Puerto Rico through family members living outside of the island (Santos-Lozada, 2017).

Forecasts that violate “best practices” described in the “demography of disaster” literature do not reflect the true population dynamics of Puerto Rico, nor can they gauge future population prospects of the island. In light of the ongoing economic reforms and bankruptcy settlements from the Puerto Rico Fiscal Plan (Government of Puerto Rico, 2018), we express concern over how poorly constructed forecasts could impact the island’s restoration efforts and funding. Not only do the rebuilding efforts require solutions to address the flailing economy, but they must also address the anticipated challenges from climate change and future climate disasters. Although Hurricane Maria was the only major hurricane to pass Puerto Rico in nearly 2-years, in the long-term the frequency of major hurricanes is growing in the North Atlantic Basin (Bender et al., 2010). More hurricanes lead to more economic disruptions, which may accelerate population decline in the near future.

In sum, there is a delicate mix of optimism and pessimism to consider regarding the restoration of Puerto Rico. On one hand, the population displacement observed following Hurricane Maria has partially reversed as residents return to the island. On the other hand, returning, existing, and prospective residents are now depending on a successful economic recovery that will likely require appropriate federal funding for reconstruction efforts. Recent analyses have concluded that disaster response has been insufficient and resource allocation has not been proportional with the severity of the Hurricanes or local needs (Willison et al., 2019). As a result, there is cause for concern regarding the long-term fate of Puerto Rico’s population, particularly if efforts are not made to rebuild Puerto Rico’s economy in a sustainable fashion that can withstand future hurricanes (e.g. debt relief, federal assistance, generation of permanent jobs, reconstruction funding, attracting industry, etc.). Although an estimated 70% of Hurricane Maria out-migrants have returned during the first half of 2018, the population will continue to decline unless the economy picks up.

## **Conclusions**

This study discusses data limitations and professional standards that should be considered for any demographic analysis of natural disaster impacts. While the paper focuses on Puerto Rico, the intent is not to prescribe a new methodology for estimating island migration. Future research and the people would benefit from the development of an alternative estimation

technique that allows us to understand post-disaster dynamics with data constraints faced following these events. In fact, research to improve Puerto Rico's data quality during hurricanes can start with recommendations from this paper and other articles in the "demography of disaster" literature. Current input data sources to Puerto Rico's population estimates from any analyst have both known and unknown coverage issues. This means their products are presented as the truth without addressing limitations or clearly establishing the assumptions underlying these results. While the BTS and the PRCS both offer valuable perspectives on Puerto Rico's population change, these sources are not robust enough to draw conclusions; nor should they be employed in population forecasts without careful consideration. On one hand, the BTS air passenger data are administrative records, and are prone to coverage error and there can be differences in totals due to the continuous update of these records. There is also a lag in the publication of the BTS air passenger data, which does not allow for the production of estimates immediately after a disaster. On the other hand, the PRCS cannot capture outmigration from Puerto Rico to other countries, struggles to capture mobile populations and also has a level of error (Kaneshiro & Pierce, 2017; National Research Council, 2007).

People invested in Puerto Rico's long-term disaster recovery efforts face many obstacles, including but not limited to debt, recession, stronger hurricanes, utilities, and sovereignty. All these challenges require robust, independent, and trustworthy socio-economic data to lay the foundation for successful private investment and public policy. As discussed, natural disasters disrupt established data sources and create a pressured environment for analysts to implement untested assumptions in forecasting models in order to produce a timely result for stakeholders. Having analyzed net migration flow out of Puerto Rico before and after the 2017 Hurricane season, we conclude that Puerto Rico's outmigration is driven by long-term declining economic conditions as opposed to population displacement induced by Hurricane Maria. In fact, dire population projections based on overstated Hurricane Maria impacts will limit Puerto Rico's ability to access credit for recovery efforts and begin addressing the many underlying economic issues. Overstating disaster impacts on population projections ultimately delays recovery, adds confusion, and could contribute to the acceleration of population decline.

This paper adds to the growing body of literature on demography of disasters. The impact of Hurricane Maria on Puerto Rico's demography is real and will be felt for several generations. At the same time, we caution against ignoring pre-existing demographic trends that are unrelated

to disasters. If anything, the increasing frequency and magnitude of large-scale disasters in recent years, their displacement effect, and the impact on the demography of affected areas, highlights the need to have higher quality and more resilient data sources for disaster-prone areas. Improved data infrastructure from proactive institutions could better serve leaders during emergencies when they demand timely information on complex issues. Higher quality data throughout a disaster's life cycle is the only way to truly disentangle pre-existing conditions from temporary shocks.

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