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Essays on Climate Change-Related Extreme Events

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ESSAYS ON CLIMATE CHANGE-RELATED EXTREME EVENTS

by

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There are increasing and urgent calls for global economies to join in the fight against the impacts of climate change (World Bank, 2020). With reports such as the World Bank (2020) of climate change costing billions of dollars in losses for economies, the purpose of my dissertation is to examine the effects of climate change-related extreme events and their potential economic effects in three areas: agriculture, migration, and the labor market.

My first essay focuses on the factors that influence farmers' perception of risk and adaptive strategies against the effects of climate change-related extreme events. I examine whether farmers' social networks play a role in their climate actions. I do this by collecting primary data in Jamaica; a developing country which has a heavy reliance on agricultural production. This study contributes to the climate change literature by investigating the perceptions and adaptation strategies of farmers in Jamaica. The results indicate three main things: (1) The presence of social networks, i.e., having nearby farmers who perceive climate change effects on livestock production or take adaptive actions, leads to greater likelihood of a farmer perceiving effects of climate change and utilizing adaptive strategies; (2) Farm size has a positive and significant effect on adaptation; and (3) farmers closer to the capital of the country are more likely to take adaptive measures relative to farmers in other parts of the country. The policy implication of this essay suggests that social networks can be leveraged to encourage the spread of climate adaptation actions.

My second essay focuses on the impact of climate change-related extreme events on migration to the US. The economic consequences of climate change-related extreme events such as storms, floods, droughts, and extreme temperature are predicted to costs billions of dollars. This study contributes to the climate change literature by estimating the effect of climate change-related extreme events on migration to the US. I do this using legal migration data from the US Department of State – Bureau of Consular Affairs and use extreme events information from the International Disaster database (EM-DAT). I find evidence that the monetary damage of storms, floods, and droughts reduce migration inflows to the US. Furthermore, I find the number of lives affected by storms reduces migration to the US. Only for the number of lives affected by extreme temperature is the effect on migration to the US positive. Both effects for the non-pecuniary damages are however economically insignificant. The findings in this essay also indicate that generally the cumulative monetary damage and cumulative number of lives affected across all events do not have a statistically significant effect on legal migration but rather it is the type or category of extreme events which affect the flow of migration to the US.

In my third essay I focus on the labor market outcomes of recent Puerto Rican migrants who moved to New York and Florida after Hurricane Maria. Using data from the American Community Survey, I test if after Hurricane Maria recent Puerto Rican migrants faced worse labor market outcomes relative to earlier arrivals. I answer this using the synthetic control method, which provides a counterfactual to answer whether the post-Hurricane Maria internal migration affected the unemployment and labor force participation rates. The results indicate that despite a large and sudden increase of recent Puerto Rican migrants, there was no significant impact on labor market outcomes.

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Alvin E. Harris

DEDICATION

To Aston Henry Harris Snr., my father.
To Beverley Calvert, my mom.
To Keveine Clarke – Harris, my love.
To myself, for surpassing my childhood expectations.

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CHAPTER 1

INTRODUCTION

Climate change is one of the greatest obstacles to countries' economic growth and development plans (World Bank, 2020). Disrupting economic and social activities, climate change-related extreme events such as storms, floods, droughts, and extreme temperature have resulted in losses amounting to billions of dollars. These are some strong indicators of the necessity for economies to consider the potential impact of climate change in their development and economic growth strategies. There is increasing evidence that due to climate change-related events, the world is expected to see increases in the number of climate migrants, reductions in food security, health concerns, and further destruction of properties (Podesta, 2019). Podesta (2019) indicated that approximately 1.9 million refugees are in need of assistance and thousands more people are expected to seek refuge because of storms and floods. As suggested by Podesta (2019), given an increase in climate migrants, countries should invest greater attention to both reducing carbon emissions and offering legal protection to climate migrants.

Without efforts to reduce carbon emissions and mitigate the effects of climate change, the future is likely to see an increase in the frequency and intensity of climate change-related extreme events (Podesta, 2019). In the context of a "climate refugee crisis" and insights about what we expect people to do and are doing, this dissertation examined climate change-related extreme events and their implications for agriculture-dependent countries, migration to the US, and the labor market outcomes for a specific group of people who moved after a climate change-related event. To simplify, my dissertation essays address: (1) the abilities and strategies that people who do not migrate have; (2) the effect of extreme weather events on the ability and decision to migrate; and (3) the labor market outcomes of those who indeed migrated.

While climate change-related extreme events may increase competition for food and increase food prices, one particular challenge for small island developing countries is the depth of climate change knowledge. The first essay in this dissertation takes an approach to understand the depth of climate change awareness among farmers and their adaptive strategies. I do this by conducting a survey of Jamaican farmers to identify their awareness and the role of social networks on their likelihood of perception and adaptation. This essay has at least two implications for climate change policy and discussion. First, there is not much understanding about what farmers in the Caribbean and Jamaica in particular know about climate change and how they and their production will be affected. This is suggested by several reports in the Caribbean such as Nurse et al. (2014) and Selvaraju et al. (2013) who reveal that fishermen and other citizens in the Caribbean have heard of climate change, but their level of awareness is limited. For risk perceptions and adaptation actions this is not sufficient given how increasingly popular the word "climate change" has become. While farmers may have heard the word "climate change" and organizations may have allocated funds to disseminate in the event of extreme events there is a disconnect between government and farmers relationship in terms of risk perception and adaptation information and options. This essay not only reveals farmers "hearing" about climate change but their deeper knowledge on the causes, importance, and vulnerable population. The essay also indicated whether farmers' beliefs would be a substantial barrier for climate policymakers to motivate climate actions. This study found that majority of farmers in Jamaica have heard of climate change and do not hold much skepticism as it relates to whether the effects are already seen.

A final implication of this essay is the role of social networks on the likelihood of risk perception and adaptation. The findings of this essay are that social networks, farm size, and location are critical to adaptation. A one percent increase in neighboring farmers taking adaptive measure increase a farmer's likelihood of adaptation by at least 1.3%. Also, an additional worker on the farm increases the likelihood of adaptation by 10.9% while being a farmer closer to the capital increases adaptation by at least 25.4%. Overall, this first investigation suggests that one action to sustain long-term productivity and income for farmers, policymakers should utilize social networks. This becomes particularly useful in areas with poor roads or remote areas. This essay also points to inequalities in adaptation. Greater efforts to target farmers in other parishes besides St. Catherine and Clarendon again could reduce farming households' vulnerability to poverty and increase agricultural productivity. Overall, this essay gives us insights on not only farmers' level of awareness but what can policymakers do to improve farmers perception of risks and adaptation. These include addressing adaptation disparities arising from farmers' location, their farm size, and the educational attainment.

Climate change-related events not only affects economic activities in terms of food production, but these events may lead to large increase in the number of climate refugees. International migration implies reduction in population size and potential depletion of human capital. In this essay, I examined whether climate change-related extreme events increase or decrease migration to the US. Theoretically, this impact can be ambiguous depending on whether the exogenous shocks affect migration costs (Mahajan & Yang, 2020). The US as a developed country is seen by many people in foreign countries as a source for income gains and thus provides a motivation for migrating. However, these extreme events impact may be substantial enough to raise the cost of migration above the affordability of people. If this is the case, then we can expect a reduction in migration flow to the US. In addition, people's migration response may depend on whether the damages from extreme events are pecuniary or non-pecuniary. The response may also depend on the cumulative pecuniary and non-pecuniary damages from all extreme events.

Taking into consideration the knowledge that international migration is not always immediate, my second essay does several things as it relates to climate change-related extreme events and their impact on migration to the US. First, I investigated the pecuniary damage of climate change-related extreme events on migration to the US. The estimation using a 2-years lag to account for the official migration process indicates that monetary damage due to floods and droughts reduce migration flows to the US. For the sample of all countries, an increase as a percent of GDP in floods and droughts reduce migration flow by 19% and 7.3% of the sample average. For low- and middle-income countries only flood damage was statistically significant and led to a reduction of 16.1% of the sample average. For the 3-years lag, the effect of pecuniary damage indicated storms and droughts reduce migration, but floods led to an increase. However, these results do not have large economic significance.

Second, this paper focused on the non-pecuniary or human impact. The results showed that storms led to a reduction in migration flows, but extreme temperature led to an increase. Overall, these results are however economically insignificant. For both the pecuniary and non-pecuniary cumulative damages I find no statistically significant effect on migration flow to the US.

Finally, alternative results were estimated in relation to climate change-related extreme events impact on migration flows to the US. These specifically were the frequency and duration of the extreme events. In general, I do not find any significant impact of climate change-related extreme events frequency and duration on migration flows to the US.

My third essay focuses on the labor market effect of recent Puerto Rican migrants' internal migration to the mainland after Hurricane Maria. The devastation of Hurricane Maria stands as the third costliest in US history. The impact in 2017 led to a large number of recent Puerto Rican migrants leaving the island for the mainland. This large and sudden influx caused by Hurricane Maria has the potential to make it difficult for those recent arrivals to find employment. To evaluate the causal impact of post-Hurricane Maria migration on labor market outcomes, I used the synthetic control method to test if post-Hurricane Maria unemployment and labor force participation rates for recent Puerto Rican migrants in Florida and New York differ from those arriving in previous years. The synthetic control method is a data-driven procedure that is appropriate to evaluate the effect of an intervention in case studies. This procedure provides several features that make it more attractive relative to traditional methods. Most notable, the method makes explicit the weights of the states in the donor pool so we can see their contribution towards the counterfactual. The method also requires that the treatment unit and the synthetic counterpart are comparable in terms of labor market predictors. The results indicated that post-Hurricane Maria migration of recent Puerto Ricans did not lead to a significant impact on unemployment rate and labor force participation rate. A caveat to these results however was the small sample size, that may give greater variations in labor market outcomes, and a favorable labor market in those states.

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CHAPTER 2

CLIMATE CHANGE PERCEPTION AND ADAPTIVE STRATEGIES AMONG JAMAICAN FARMERS

2.1. Introduction

Agriculture today faces numerous challenges ranging from increased food demand to deteriorating natural resources and biodiversity (Sadler et al., 2016). Adding to the existing challenges is the potential impact of climate change. Global warming is predicted to reduce current crop yields and climate change-related extreme events are expected to cause devastating effects on farming production and resources (Sadler et al., 2016). In the wake of these events, there is little evidence on whether farmers are perceiving climate change effects on their production. This step is critical because the adaptation process requires farmers to first understand and perceive climate change effects as well as have the knowledge and resources to respond appropriately. In this paper I present the results of this using primary data collected from Jamaican livestock farmers.

The challenge for Jamaica's agricultural sector and the Caribbean in general is that for farmers there is a dearth of information about their knowledge of climate change, their perceptions of the risks, and potential adaptation measures. The issue here is that not much is known about how agricultural stakeholders or the government of countries in the region intend on addressing the effects of climate change-related events on production. This becomes an economic and social issue that requires policy guidance for the region in general and Jamaica specifically as they depend on agricultural production as a means for economic growth and is the sole source of income for some farmers. The main objective of this paper is to provide descriptive and empirical evidence of how climate change-related events may affect farmers and their agricultural production not just applicable to Jamaica but in similar countries. I attempt to provide this evidence by conducting a field study which aims at understanding farmers' awareness of climate change and their responsive strategies to the effects. First, I investigated the question of farmers awareness of climate change. Second, I investigated the methods chosen by farmers to mitigate the effects of climate change-related events. Finally, I evaluated the factors influencing farmers' perceptions and adaptation.

The predictions for Caribbean countries are that climate change will have large economic and financial costs (Simpson et al., 2012). For the region, an average of 23% of workers are employed in agriculture, but this share of employment goes as high as 62% for some countries (Ramasamy, 2013). According to 2005 figures, Jamaica's agricultural value added was $669 million USD and the agricultural labor force was 18.14% of total employment (Simpson et al., 2012). Agriculture contributed 7.1% to Jamaica's Gross Domestic Product (GDP) in 2018 and remains one of the four main pillars in the goods sector (PIOJ, 2018). These statistics highlight not just the importance of agriculture to employment but also to economic growth for Jamaica and the Caribbean region. It also implies that current climate change predictions could impact economic outcomes, including poverty and increased food insecurity.

The region is likely already seeing the adverse effects of climate change-related events. The United Nations reports that despite contributing a negligible amount of greenhouse gases, Small Island Developing States (SIDs) are predicted to be impacted the earliest and most severe by climate change (Simpson et al., 2012). The Caribbean SIDs have incurred economic and financial losses of $10 billion USD (approx. 13% of GDP) due to weather related events (Simpson et al., 2012). Estimates show that by 2050, SIDs will experience reduction in agricultural production due to climate change and specifically for the Caribbean losses are predicted to range between $85 million and $243 million USD per year (Simpson et al., 2012). These consequences of climate change to the agricultural sector in SIDs motivate the questions addressed in this paper.

There is a dearth of literature highlighting the impact and threat of climate change to farmers in the Caribbean and SIDs more broadly. Most of the literature examining the impact of climate change on farmers in developing countries focused on the African continent and India. Nonetheless, this work can still inform research in SIDs. In Ethiopia, Addisu et al. (2016) and Deressa et al. (2011) investigated the perceptions and adaptive responses of farmers. Both studies found evidence that farmers' individual, farm, and household characteristics influence their perception of climate change. In South Africa, Hitayezu et al. (2017) found farmers who have more emotive mental imagery and egalitarian values were more likely to perceive the risk of climate change.

For climate change adaptation in the agriculture context, there are several questions being asked as it relates to the influence of peers, the potential strategies for policymakers, and awareness of farmers. This paper makes four contributions to the economic and environmental literature. First, to the best of knowledge this is the first study of climate change awareness among livestock farmers in the Caribbean region. Second, this study demonstrates the potential importance of social networks; how neighboring farmers detecting climate change-related effects on their livestock could lead to the dissemination of information that changes the likelihood of other farmers detecting such events on their production. The third contribution is highlighting the extent to which Jamaican farmers are aware of climate change and whether they feel it impacts their livestock. The fourth contribution is to highlight the strategies of Jamaican farmers to mitigate the impact of climate-related events. These contributions highlight whether farmers have adequate knowledge of the threat climate change present to their livestock production and are they clear on how climate change is manifested. It also signals to policymakers and researchers farmers' practices and readiness to effectively deal with climate change.

This study has several findings. First, I find that majority of Jamaican farmers have heard about climate change, believe it is a significant issue to address, and understand it has implications for both their households and livestock. However, most farmers do not have a practice of keeping up with climate information and may therefore be unprepared for climate change-related events. Second, I find that more than half of farmers experienced adverse effects of drought on their livestock production. For those reporting adverse effects, half took adaptive measures; the most common of which was to change where animals feed. Almost half of farmers experienced adverse impact of flooding on their livestock. In response to flooding effects, many farmers took adaptive measures, the most common was making changes to the pens. Third, and finally, I find that the size of a farmer's social network perceiving climate change effects on production have a statistically significant effect on farmers' perception as well as the percent of farmers taking adaptive measures on the likelihood of adaptation. I find that a farmer's probability of perceiving climate change-related effects is positively affected by an increase in the percent of farmers within their social network who perceive climate change-related effects on their livestock. This finding is particularly important to policymakers in agriculture-dependent countries, where infrastructure development is not always ideal. For example, the role of social network could prove particularly useful if policymakers have the objective of increasing climate change information among farmers, but it is difficult to reach them because of poor roads, an inconvenient time for the farmers, or their location is difficult to reach.

2.2. Literature Review

2.2.1. Climate Change Literature

There is a growing literature exploring the impact of climate change-related events on agriculture and how climate change policies may help stakeholders mitigate its effects to ensure the sustainability of the sector. For some economies, agriculture is one of the main contributing sectors to economic growth and development (Howden et al., 2007). However our knowledge of the impact of climate change on smallholder or subsistence farming needs additional research (Morton, 2007). Long-term shifts in rainfall variability, heat, and other climatic parameters impact crop and animal production - threatening not only food security but the health of livestock. The projected impact of climate change on agricultural production, food security, economic activities, and health puts the onus on stakeholders to identify and assess adaptive strategies (Howden et al., 2007).

Research, such as Adams (1989), estimated the present effects of climate change on agriculture in a developed country context and found negative consequences for agricultural production. Also in a developed economies context, Smit & Skinner (2002) developed a "topology of adaptation" that characterized adaptation options for agriculture in Canada. The topological analysis raised four critical areas as a guide for farmers to adequately respond to the adverse effects of climate change. The first is the adaptation option, which involves technological development such as improvement in crops and weather information. The second area includes government programs and insurance, which are essentially agricultural subsidy and support programs. The third area involves improvement in farm production practices such as diversification and intensification of crops and livestock production. The final option is farm financial management which covers "investment in crop shares and futures, participation in income stabilization programs, and diversification of household income" (Smit & Skinner, 2002).

Developing countries have garnered the interest of academic and policymakers because of their likely limited capacity to adapt to climate change. Ultimately, sustained agricultural growth depends on farmers' adaptive capabilities. According to Barnett (2001) and Whitmarsh (2011), whose studies focused on Pacific Island Countries and the United Kingdom respectively, adopting measures to mitigate the effects of climate change is hindered by skepticism of the presence of climate change and the uncertainty of the occurrence of climate related events. However, today that may have changed largely due to efforts by activists, international organizations, and researchers who have brought greater recognition and evidence of global warming. For Grimberg et al. (2018) political views also influence perceptions of climate change while socio-ecological characteristics determine adaptive strategies. Grimberg et al. (2018) found that more than half of respondents are "concerned or alarmed" about climate change and a larger proportion concerned about its impact on agriculture now and in the future. Overall, Grimberg et al. (2018) note most participants are aware of climate change but their perceptions on the causes, severity now and for the future are heterogenous.

The Intergovernmental Panel on Climate Change (IPCC) states "the vulnerability of systems to climate change is influenced by actual exposure to climate change, their sensitivity and adaptive capacity" (IPCC, 2001). This signals that climate resilient adaptive strategies should be developed in ways that potential damages can be controlled, opportunities are taken advantage of, and systems may be able to cope with the consequences. Reidsma et al. (2010) measured adaptive capacity by the interaction between farm characteristics and temperature. The study found regional differences and larger farms, which are deemed “richer,” have worse adaptive strategies compared to poorer farmers who adapt much better to climate variability.

Seo et al. (2005) estimated the impact of climate change on agriculture in Sri Lanka. By taking a Ricardian approach, the authors make use of economic data on the value of land and thereby correct for the bias often resulting from the traditional production function approach. They found that the sector stands to benefit by about 72% from rainfall increases but its output would be adversely impacted and likely decrease by 20% due to temperature increases. However, it is unclear the extent to which citizens and farmers believe in climate change, are aware of the symptoms of climate change, are taking measures to address the negative impact, or are aware of the appropriate measures to mitigate the unfavorable effects.

Below et al. (2015) evaluated the perception of farmers in two Tanzanian villages. The study found a clear distinction between the two communities in relation to climatic and yield dynamics. Farmers’ actions were dependent on their belief of the trajectory of climate change-related issues and the type of benefits they receive from the local agricultural system. In Kenya, Silvestri et al. (2012) note that most households are cognizant of the effects of climate change. However, lack of liquidity and access to inputs and land prevented farmers from taking appropriate measures for adaptation. In addition, livestock farmers have great difficulty addressing climate change due to inaccessibility of additional or new breeds of animals.

For some farmers, updating their belief about climate change is slow as suggested by Maddison (2006) and Kolstad et al. (1999) and thus may (1) never implement climate resilient plans; or (2) be able to correctly perceive change in climatic parameters and put in place measures before it is too late. Farmers’ misidentification of climate change as well as the costs associated with adaptation also is a challenge (Maddison, 2006). For farmers to take climate action, they first must have knowledge about the issue, be able to identify, know, and implement strategies that are useful to mitigate any harmful effects.

Using the one way ANOVA approach to assess climatic stressors, farmers' socioeconomic characteristics, and climate change perceptions for cabbage and potato farmers, Elum et al. (2017) found that most farmers are aware of climate change and their perceptions are similar to official data. Between the types of farmers, the ANOVA analysis indicated there were significant differences in the portion of irrigated land, the number of workers employed, and the net revenue earned. However, robustness checks indicate this was random.

While most of the climate change and agriculture literature focused on crop production, studies like Bett et al. (2017), Hristov et al. (2018), and Rojas-Downing et al. (2017) highlight climate change specific impacts on livestock. Hristov et al. (2018) study examined the effect of climate change on livestock production. They found increases in temperature are likely to reduce cattle fertility and induce heat-stress which in turn reduces livestock energy levels. In their study Bett et al. (2017) highlight the evidence that there is a positive association between the effects of climate change and the spread of livestock diseases. For Rojas-Downing et al. (2017) there is a bi-directional link between climate change and livestock production. The study suggested livestock production is expected to decrease due to the spread of diseases and reduction in water availability. On the other hand, livestock production has been found to contribute 14.5% of global greenhouse gases emissions. Grimberg et al. (2018) reiterate the threat of heat stress and low water availability on livestock, emphasizing how extreme drought and heat led to livestock death.

There are competing methodologies to estimating the effect of climate change on perception risks and adaption. Some studies use binary dependent variable models such as probit or logit while others use multinomial techniques. However, Addisu et al. (2016) and Deressa et al., (2011) use the Heckman model while Hitayezu et al. (2017) use the double hurdle model. Both approaches are based on the understanding that farmer adaption strategies are a two-step process. Because farmers often perceive the problem before adopting adaptation strategies, two stage econometric models such as the double hurdle, Tobit, and Heckman models are most commonly used in this literature.

Deressa et al. (2011) and Maddison (2006) use the Heckman model to investigate perceptions and adaptations of farmers in the Nile basin of Ethiopia and 11 African countries respectively. The results indicated that farmers' experience plays a significant role for whether they choose adaptive strategies. In addition, the results showed the head of the household is likely to take adaptive measures – which the authors conclude was due to their control of the household's resources.

Hitayezu et al. (2017) use a double-hurdle model, an alternative two-step approach, to examine the nexus between farmers' perceptions and socio-psychological, cultural, and institutional factors. The first hurdle is that farmers are "potential perceivers" and the second hurdle is that "given positive perceptions, socio-psychological, institutional, and cultural scenarios lead to actual perceptions". The authors found that "adaptive impressions and egalitarian values" are associated with perceiving climate change. This implies that personal experience with shifts in climate increases the likelihood of perceiving climate change-related events effects.

2.2.2. The Role of Social Networks

The ability to perceive and adapt to climate change-related effects is not limited to socio-economic factors but can be due to the flow of information between decision makers and the influence of their peers, neighbors, or social network, on their actions (Ramirez, 2013). In social science literature, the incorporation of social network influence is critical to understanding particular outcomes (Videras, 2013). In this study, the use of social network is meant to provide us with an additional channel that captures farmers' ties and how information and ideas flow to change behavior. A social network refers to the relationship among individuals and the interconnectivity between them which functions as a medium for information diffusion (Maertens & Barrett, 2013). This flow of information may be unidirectional or bidirectional. That is, information may flow from more experienced farmers to amateurs or the information may flow between both types of farmers.

Social networks within the farming sector can be a crucial avenue for the adoption of technology since the percent of farmers experiencing climate change-related effects on production may affect the probability of a farmer detecting similar effects on their production (Abid et al., 2017; Maertens & Barrett, 2013; and Mekonnen et al., 2018). The role of social network could be pivotal to climate actions since most farmers do not act independently. but rather share information and ideas, collaborate, and act in subjectively productive ways (Ramirez, 2013). Ramirez (2013) summarizes three pillars of social networks: (1) family; (2) land leasing; and (3) external knowledge. The social interaction among family members (e.g. father to son) leads to the transfer of knowledge that guides farming practices and responses to environmental issues. The second channel occurs whenever a tenant uses some technology. If there is a new tenant, they are more likely to adopt the same technology as the previous tenant. That is, because tenants are indirectly connected through landowners, one’s decision or practice can influence the other (Ramirez, 2013). The third way social networks become important is through farmers’ relationship with other communities, clubs, and government services which provide information of farm practices.

Ramirez (2013) study found that the diffusion of knowledge for farmers came through a social network of peers such as family members and other farmers. In addition, Ramirez (2013) stated farmers observe their peers’ practices in order to be convinced of the efficiency of such mitigative strategies. One of the main reasons the peer effect is influential is due to the trust farmers have among each other. These indicate why social networks may be a key source that informs policymakers and researchers about the diffusion of information.

Manski (1993) emphasized that identifying and measuring the effect of social networks is important. The first step to doing this is identifying appropriately who is in a farmer’s network – who are they most likely to have some social interaction. Similarly, Maertens & Barrett (2013) put forward the following questions that pertain to social learning: what type of information do farmers absorb and from whom? And how do farmers update their belief? Do these beliefs lead to actions? Maertens & Barrett (2013) conclude by suggesting geo-referencing using GPS locations as one way to control for potentially confounding variables.

Hou et al. (2015) used three measures of social network to examine the influence of Chinese farmers’ perceptions of climate change and how consistent are they with meteorological data. These measures include whether villages have a farmers’ organization, the number of farmers within three (3) generations, and whether relatives serve as village leaders. Hou et al. (2015) found that social networks, in the forms of farmers belonging to an organization and an increasing number of relatives within 3 generations, positively impact farmers’ perceptions of temperature changes.

One theory that helps us understand the working of social networks is contagion theory. Pertaining to this study, contagion theory suggests that farmers will adopt the behaviors of their social peers even though it may be the case their peers did not intend to influence their behavior (Scherer & Cho, 2003). This implies that the behavior of one member of the community may affect the risk perceptions associated with climate change-related events. Scherer & Cho (2003) however state that studies have not reached a conclusion on the extent of this influence on some topics. They examined whether similarities in risk perceptions are related to the strength of social networks and whether topics not likely to promote personal interactions would be related to the strength of the network as well. They found that strong social network ties were related to similar risk perceptions of an event but not related to "non-controversial measure of the belief in science." A shortcoming of the analysis is whether the results are causal. The problem of cause and effect arises because it is possible individuals may seek out others with similar perceptions thus forming a social network or, alternatively, the social network may arise due to social proximity (Scherer & Cho, 2003).

In the case of climate change, Cunningham et al. (2016) suggests that social networks are applicable to examine farmers' perceptions and actions to climate change effects. Cunningham et al. (2016) examined how social networks and social network analysis (SNA) could help policymakers engage a community in Shoalhaven, Australia in climate adaptation action. They found that by identifying key points (nodes) through which information is disseminated quickly, SNA can be useful for policymakers to engage the public in climate action.

2.3. Study Context, Data, and Empirical Strategy

2.3.1. The Study Area

Jamaica is the third largest country in the Caribbean region; a tropical humid zone which generally has temperature ranging between 22°C and 32°C. Being an island in the tropical zone implies Jamaica could be more vulnerable, relative to other countries, to hydro-meteorological events such as unpredictable rainfall patterns, extreme temperature, flooding, and sea level rise (Association of Caribbean States, 2017). Predictions are that Jamaica and other SIDs in the Caribbean face both physical and economic losses from climate change in the tourism and agricultural sectors. The Association of Caribbean States (2017) reports that tourism composed 14.8% of GDP and 12.9% employment in the Caribbean. The implication of this is $22 billion in losses due to adverse effects of climate change. This estimate however excludes lower intensity but more frequent events. For Jamaica specifically, the losses due to climate change are possibly already being felt. Above normal rainfall in 2017 led to significant damages of crops and livestock. Each quarter in 2017 saw reduction in agricultural output, with the second quarter recording losses of $792.4 million (PIOJ, 2017). This however was addressed by the government's Flood Recovery program which helped to stimulate growth in the sector for 2018. The predictions are that increased occurrence of flooding could again result in substantial economic losses for Jamaica's agricultural sector.

This study investigates farmers' perceptions of climate change and the strategies taken to address climate change by farmers in 5 parishes across Jamaica. The sampled parishes are Trelawny, St. Elizabeth, Manchester, Clarendon, and St. Catherine. Figure 2.1 shows the exact location of all parishes in Jamaica.

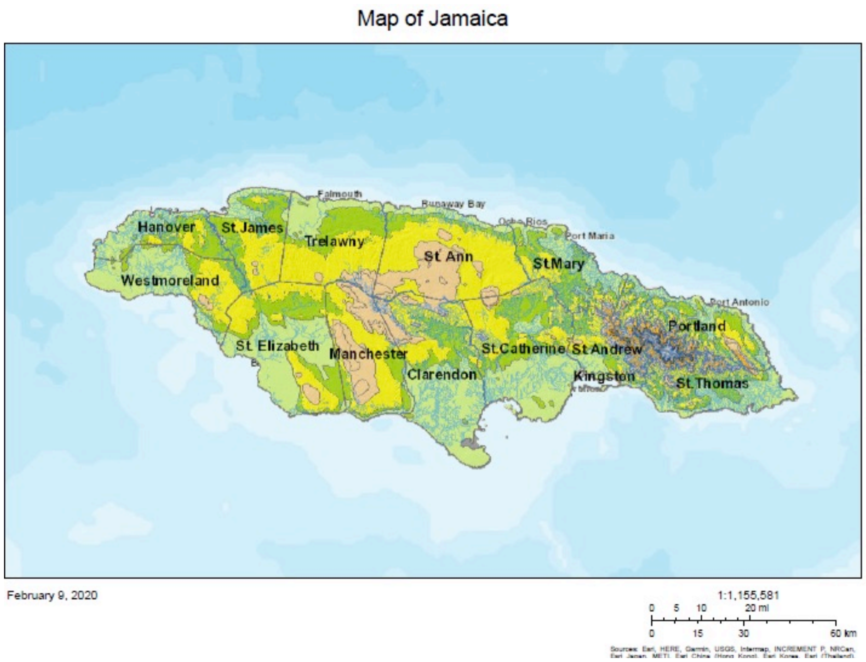

Figure 2.1 Map of Jamaica (Source: Jamaica National Land Agency)

These parishes predominantly engage in agricultural production which for some is the main source of livelihood. The households surveyed are livestock farmers, with some engaging in crop production[1]. Though a small country, the parishes experience rain and temperature variability (Simpson et al., 2012). Consequently, the impact of climate change may not be uniform across parishes; making some farming activities more vulnerable to long-term changes in the environment.

2.3.2. Data Collection

To carry out the analysis I use primary survey data from livestock farmers in Jamaica[2]. This data was collected in two rounds between January and March 2019. In the first round, the

[1] This survey is an extension of a study of praedial larceny affecting Jamaican livestock farmers.
[2] Appendix A shows the Human Subjects Institutional Review Letter of Approval.

farmers' demographic data were collected, and the second round collected additional information on their perception of climate change and adaptive practices. The first-round survey focused primarily on praedial larceny (livestock theft) which is a serious issue affecting Jamaica's agricultural market. In the second round, a follow-up survey was conducted with the aim of understanding how weather patterns are affecting farmers' agricultural production. To be able to assess the factors that influence farmers' climate change perception and adaptation practices, the follow-up survey data are combined with the first-round data.

For each interview, farmers were asked questions related to their perception of climate change, how it has impacted them, the perceived causes and importance, and how they have responded. Table 2.1 shows the percent of farmers from the five parishes[3] used in this survey.

Table 2.1
Percent of Farmers in the Respective Parishes.

Variable	Obs.	Mean
Clarendon	167	0.401
St. Catherine	167	0.371
St. Elizabeth	167	0.120
Manchester	167	0.042
Trelawny	167	0.066

Table 2.1 shows the percent of farmers of the total sample that resident in each of the 5 parishes.

Table 2.1 shows the distribution of the 167 farmers with respect to their parishes. From an official list of farmers in Jamaica, we randomly sampled farmers in each parish[4]. As shown, 40% of the farmers are in St. Catherine, 37% in Clarendon, 12% in St. Elizabeth, 4.2% in Manchester, and 6.6% in Trelawny. In relation to collecting farmers' responses, the enumerators met with the

[3] In this paper, eastern parishes refer to the parishes of Clarendon and St. Catherine. A parish is the main unit of local government and in one sense, because each has capital, is synonymous to a state in the US. However, its legislative power is limited.
[4] The number of farmers randomly surveyed is reflective of the percent of farmers in each parish based on the official list.

farmers at their homes or their farms to conduct the interviews – recording the responses on mobile tablets.

Similar to Harvey et al. (2018) the design of the survey reduced the likelihood of farmers knowing the survey was about climate change. The questions asked were divided into five sections: (1) flooding or too much water; (2) droughts or too little water; (3) temperature; (4) lifetime observation of weather patterns; and (5) knowledge of climate change.

2.3.3. Methods and Models

The goal of this paper is to examine the factors that are important in whether Jamaican farmers perceive the effects of climate change and what factors determine the likelihood they will choose adaptive methods. For farmers to be able to adapt to the effects of climate change, they first should be able to perceive the effects of climate change. An applicable method for this feature is the Heckman probit model. The Heckman model is specified as follows:

$$y_i^* = X_i\beta + \mu_{1i} \tag{2.1}$$

$$y_i^{probit} = y_i > 0 \tag{2.2}$$

$$y_i^{select} = (Z_i\gamma + \mu_{2i}) > 0 \tag{2.3}$$

Equation (2.1) is the latent equation which illustrate the relationship between decision to adapt and other hypothesized factors. The binary outcome of equation (2.1) is only observed if equation (2.2) holds. The dependent variable for observation i is observed if equation (2.3) is the case. That is, if farmers perceive the effect of climate change. We also assume that $\mu_1 \sim$

$N(0,1), \mu_2 \sim N(0,1)$ and $corr(\mu_1, \mu_2) = \rho$ and that when $\rho \neq 0$ the estimates of the first equation are biased.

To understand the factors which affect farmers' perceptions and whether they will engage in adaptation, this study includes several independent variables which are included in the vector X_i. Addisu et al. (2016) and the relevant literature covered in Section 2.2 provides support for the variables and their hypothesized sign. The included variables capture household characteristics, farm information, and knowledge of climate change. Household characteristics include age, education, gender, household size, and wealth status. The effect of age on perception and adaptive strategies is ambiguous. For example, younger individuals may be able to understand what climate change is and therefore be able to perceive it. In addition, they on average will outlive their older counterparts and therefore may have greater incentive to mitigate the effects of climate change. On the other hand, older farmers could also be more likely to perceive climate change and have more knowledge on the appropriate strategies to employ. The expected sign of education is positive. Higher levels of education may be correlated with knowing about climate change. The expected sign on gender, household size, and wealth status is ambiguous. This study includes two measures of farm size: (1) the total number of workers on the farm, and (2) the total number of livestock reared by farmers. Social networks, which was discussed in Section 2.2.2, are of particular interest to this study and serves as a channel to identifying the variables that influence adaptation.

The effect of social networks is captured by (1) the percent of farmers in the sample within a 10km radius who have perceive climate change-related effects on their production and (2) the percent of farmers in the sample within a 10km radius who have taken adaptive measures against climate change-related events. The role of social networks is one that would be important to farming practices. The intuition behind social networks is that once a farmer has contacted another, who is most likely close by, they will maintain that communication with their peers. Continued communication does not necessitate physical presence but with the prevalence of telecommunications platforms, information and ideas can be easily shared. In fact, Beaman & Dillon (2018) and Manson et al. (2016) found that information related to agriculture technological adoption decline with greater social distance. For perceiving climate change risks, farmers can communicate with trusted peers in their social networks about how their livestock production is affected by floods, droughts, and temperature increases.

Therefore, social networks may play a pivotal role for farmers and can overcome barriers that would otherwise be difficult to overcome (Mekonnen et al., 2018). The expected sign of the effect of social network is positive. It is expected that if the percent of farmers within a social network that is perceiving climate change effects increases, this risk perception information will flow to others. In addition, an increase in the percent of farmers who have taken adaptive measures is expected to increase the probability of a farmer's ability to better perceive climate change-related effects on their livestock. Social networks as defined by this study serves as the exclusion restriction in the Heckman probit model. The first measure of the social networks variable is included only in the sample selection equation and not the adaptation equation as increases in the percent of farmers detecting climate change-related effects on their production may only increase the likelihood of other farmers becoming aware of similar effects but this does not affect whether such other farmers are more or less likely to take adaptive measures.

While there are reports on the potential impact of climate change on small islands and on agriculture in Jamaica, these reports made no declaration on the extent of climate change awareness among Jamaican farmers and citizens. According to Nurse et al., (2014) small islands do recognize that climate change pose risks but there is limited discussion and a lack of deeper awareness of ways in which they will be impacted. This lack of awareness may lead to increased risk. In Jamaica, Selvaraju et al. (2013) reported on climate change adaptation for Jamaican fishermen. One of the highlights of their paper was fishermen's unawareness of methods to reduce their vulnerability to climate change. In light of these reports, I do expect to find that most farmers have heard of climate change but on the other hand I do expect to find differences in perceptions, adaptation, impacts, and causes of climate change being reported by farmers. Further, to identify the factors that influence adaptation I include a measure of social networks that captures the percent of farmers within a 10km radius who detected climate change-related impacts on their production. This variable serves as the exclusion restriction in the Heckman probit model. As indicated by Selvaraju et al. (2013) the creation of a deeper awareness of climate change-related impacts on production is a vital channel for farmers and individuals to not only perceive the effects but cope. In the model presented above, this first measure of social networks is included in the selection model.

2.3.4. Descriptive Statistics

In addition to econometrically evaluating the variables impact on the probability of adaption, this survey also presents descriptive information which increases our knowledge about Jamaican farmers. In this subsection, I present descriptive statistics that adds critical information about farmers both for the general public and policymakers.

Table 2.2. summarizes flooding information. We see that almost half of farmers (48.5%) report having experienced adverse effects on production due to flooding. For majority of these farmers, the adverse effects from flooding were during the years of 2017 and 2018[5].

Table 2.2
Flood Experience, Flood Effects, and Flood Prevention Strategies.

Variable	Obs.	Mean	Variable	Obs.	Mean
Flood experience	167	0.485	Death (0)	81	0.198
Flood experience (2018)	81	0.506	Death (1-5)	81	0.222
Flood experience (2017)	81	0.543	Death (6-10)	81	0.173
Flood experience (2016)	81	0.469	Death (>10)	81	0.407
Can't recall year	81	0.074	Flood management	81	0.753
Less food	81	0.296	Livestock to crop	61	0.033
Stunt growth	81	0.185	Regenerate grass	61	0.115
Death	81	0.741	Change where animals feed	61	0.262
Dehydrated	81	0.049	Changes to pen	61	0.869
Reduced fertility	81	0.272			
Parasite	81	0.247			
Other	81	0.407			

Table 2.2 shows information on the percent of farmers who have experienced flooding and the respective years they experienced such disaster. The table also shows the percent of farmers and what they indicated to be the effect of flood along with their chosen method to adapt to flooding.

The effects appear to be detrimental and substantial as only 20% of farmers reported no loss of livestock due to flooding[6]. Over 75% of farmers who experienced negative effects on production took adaptive measures. These farmers were largely making changes to the livestock housing (86.9%) and finding new areas for animals to feed (26.2%). These statistics suggest that most farmers are responsive to flooding effects and although there is some variation in their chosen method to mitigate future effects on livestock production, this is largely making changes to the pen; a method that may not be sustainable for the long-term given the predictions of climate

[5] Farmers were surveyed on whether they experienced adverse effects on livestock from production. Those who responded in the affirmative, were asked which year(s) they had that experience.
[6] It is important to note that this loss is more substantial for farmers whose operations are lower. For example, a farmer whose operation consists of 20 livestock loses 10 could face serious damage to their operation relative to a farmer who has 200 livestock and loses 10.

change-related events. I further delve into the impacts of flooding on livestock at a more disaggregated level. Figure 2.2. shows farmers in Clarendon and Trelawny has greater experience with flooding effects on production, relative to farmers in other parishes.

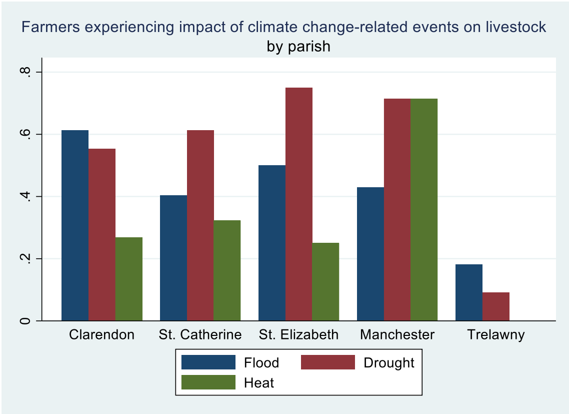

Figure 2.2 Farmers Experience of Flooding, Drought, and Heat Effects on Livestock Categorised by Parishes

Further, Figure 2.3 shows that across all parishes, a higher percent of farmers took some measure against flooding compared to the other types of climate change-related extreme events.

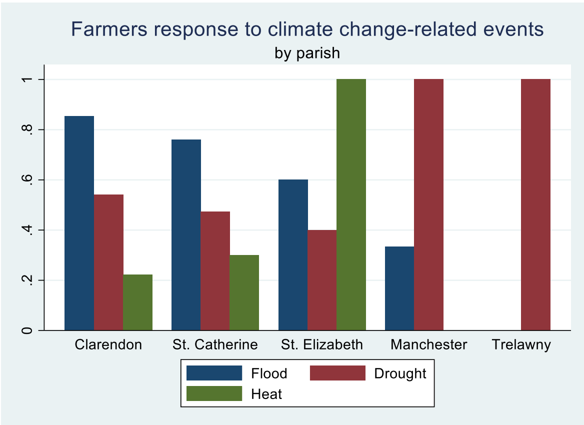

Figure 2.3 Percent of Farmers who Respond to Climate Change-Related Events

In addition, as shown by Figure 2.4, Clarendon is also the parish experiencing the most severe loss of livestock due to flooding while Manchester farmers recorded the lowest loss of livestock.

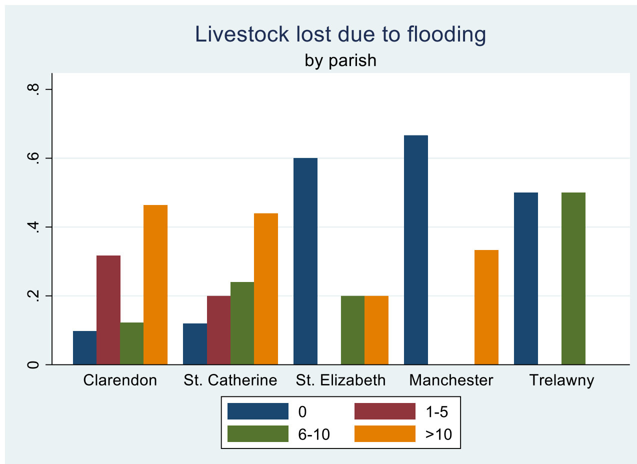

Figure 2.4 Percent of Farmers who Indicate the Number of Livestock Lost due to Flooding.

In Table 2.3., I present the responses to drought-related questions. More than half of farmers (57.5%) report having production being negatively affected by droughts.

Table 2.3

Drought Experiences, Drought Effects, and Drought Prevention Strategies.

Variable	Obs.	Mean	Variable	Obs.	Mean
Drought experience	167	0.575	Drought Death (0)	96	0.427
Drought experience (2018)	96	0.563	Drought Death (1-5)	96	0.417
Drought experience (2017)	96	0.781	Drought Death (6-10)	96	0.125
Drought experience (2016)	96	0.854	Drought Death (>10)	96	0.031
Can't recall drought year	96	0.063	Drought management	96	0.521
Less food	96	0.917	Livestock to crop	50	0.020
Stunt growth	96	0.354	Goats to other animals	50	0.020
Death	96	0.375	Regenerate grass	50	0.420
Dehydrated	96	0.156	Change where animals feed	50	0.820
Reduced fertility	96	0.094	Changed pens	50	0.180
Parasite	96	0.094			
Other	96	0.115			

Table 2.3 shows the percent of farmers who have experienced drought effects on their production as well as the respective years, if they can recall. The table also indicate the percent of farmers indicating the outcome of droughts and their chosen method to mitigate its effects.

While more than half experienced negative drought effects in all years, this was most frequently reported for 2016 and 2017. Among those who experienced drought effects, the most significant consequences of droughts were less food (91.7%) and the death of at least 1 livestock (57.3%). Nonetheless, most farmers harmed by droughts took adaptive strategies to reduce its effects. To combat the negative outcomes, farmers main actions were changing where the animals feed (82%) and finding ways to regenerate grass (42%). Figure 2.2 also shows the parish which is most affected by droughts. St. Elizabeth and Manchester were the most affected parishes by drought. The percent of farmers responding to drought effects was lowest in St. Elizabeth and highest in Manchester and Trelawny (Figure 2.3). In terms of livestock losses, Figure 2.5 shows this was more severe for Manchester, as 60% of farmers loss between 1 and 5 livestock due to drought effects.

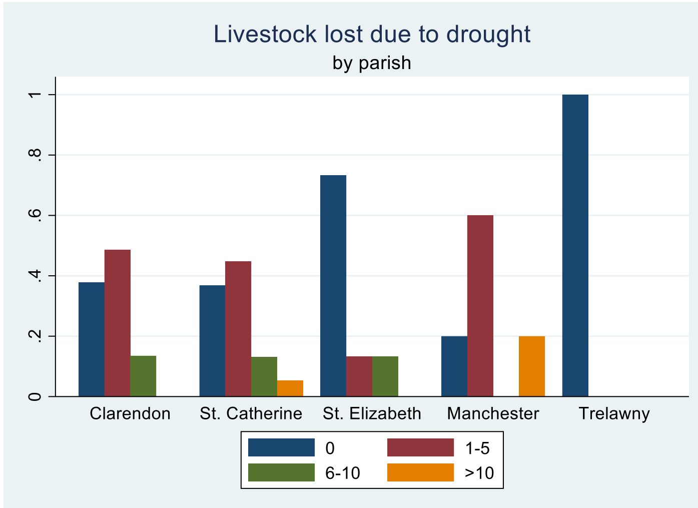

Figure 2.5 Farmers Response on Number of Livestock Lost due to Drought Effects

In Table 2.4, I report farmers' responses to heat effects on livestock production. The table shows that 28.7% of farmers indicated that heat had negatively affected their livestock production. Among those who indicated such, they have consistently seen the effect for each year between 2016 and 2018, with 87.5% of farmers who experience heat effects did so in 2017.

Table 2.4
Heat Experiences, Heat Effects, and Heat Prevention Strategies.

Variable	Obs.	Mean	Variable	Obs.	Mean
Heat experience	167	0.287	Death (0)	48	0.542
Heat experience (2018)	48	0.646	Death (1-5)	48	0.188
Heat experience (2017)	48	0.875	Death (6-10)	48	0.042
Heat experience (2016)	48	0.708	Death (>10)	48	0.229
Can't recall heat year	48	0.021	Heat management	48	0.313
Less food	48	0.688	Regenerate grass	15	0.467
Stunt growth	48	0.250	Change where animals feed	15	0.533
Death	48	0.292			
Dehydrated	48	0.208			
Reduced Fertility	48	0.125			
Parasite	48	0.167			
Other	48	0.208			

This table indicates the percent of farmers who have experienced adverse heat effects on their production and the respective years. In addition, farmers also indicate the perceived outcome of this adverse heat effect, and their chosen method of adapting.

Farmers report that the heat effects mainly resulted in less food being available for livestock with the second highest effect being death of livestock. For heat effects, only 31.3% of farmers chose to take adaptive measures, with the only two options being regenerating grass and changing where animals feed. Among all parishes, the highest percent of farmers (70%) experiencing heat effects are in Manchester (see Figure 2.2). However, as Figure 2.3 shows, none of the farmers in Manchester took responsive measures against heat effects. Rather, the highest percent of farmers responding to heat effects are from St. Elizabeth. In addition, 60% of farmers reported between 1 and 5 livestock deaths due to heat effects (see Figure 2.6 below).

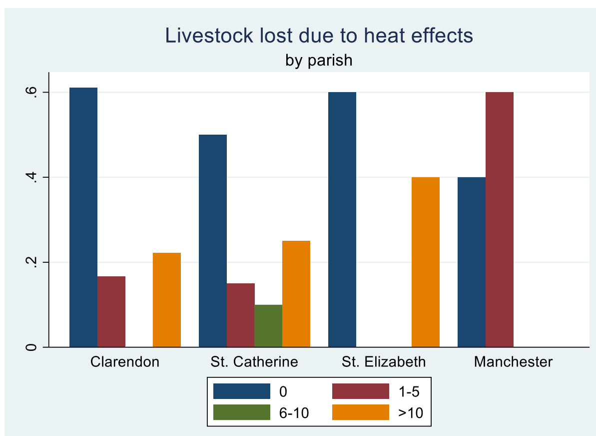

Figure 2.6 Farmers Response on Livestock Lost due to Heat Effects

I report in Table 2.5 farmers' knowledge of climate change, their risk perceptions, relevance of addressing climate change, and the percent of farmers in their social network positively perceiving climate change effects on production.

Table 2.5
Knowledge of Climate Change, Perceived Lives at Risk, and Importance.

Variable	Obs.	Mean	Variable	Obs.	Mean
Heard of climate change	167	0.934	Personal impact only	156	0.013
Social network perception	167	0.833	Livestock impact only	156	0.051
Very important	156	0.641	Personal & livestock	156	0.827
Important	156	0.244	Neither	156	0.045
Not very important	156	0.077	Unsure	156	0.064
Not important	156	0.038			

This table shows the percent of farmers who have heard about climate change, whether they think either them and/or their livestock are at risk to the effects of climate change, and the importance of addressing climate change.

From the sample of farmers, 93.4% of farmers have heard the word ‘climate change’. In addition, a large percent of the farmers who have heard of climate change believe both they and their livestock will be affected by climate change. Together, 84.5% of farmers indicate that climate change is an important issue requiring immediate solutions. A majority of those (64.1%) believe addressing the problem of climate change is very important. When looking at a farmer’s social networks, we observe that on average 83.3% of farmers within a 10 km radius are perceiving climate change effects on their livestock production. In Figure 2.7, I present information at the parish level on farmers knowledge of climate change and their personal belief.

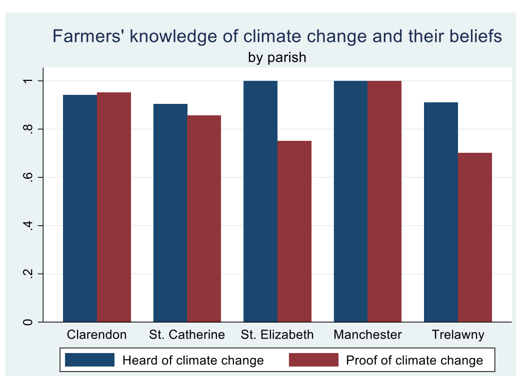

Figure 2.7 Farmers Awareness of Climate Change and Belief

We see that all farmers in St. Elizabeth and Manchester have heard about climate change but only in Manchester do we see the same percent agreeing there is proof of climate change. In all parishes at least 79% of farmers indicated climate change effects will likely have adverse effects on their lives and their livestock production (Figure 2.8).

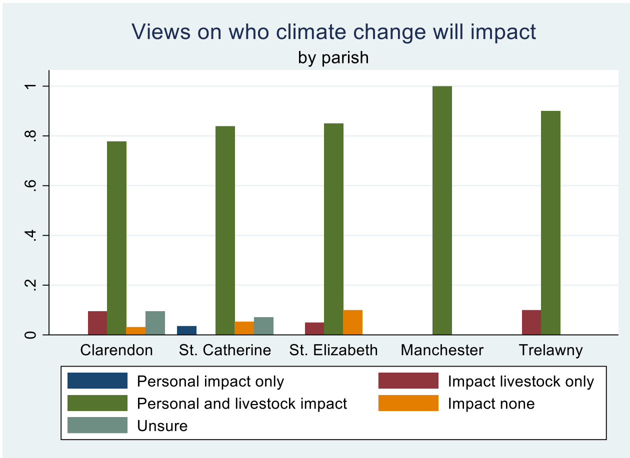

Figure 2.8 Farmers' Views on who Climate Change Will Impact.

From Figure 2.9, only in the parish of Manchester do we see more farmers indicating that climate change is an 'important' issue rather than a 'very important' issue.

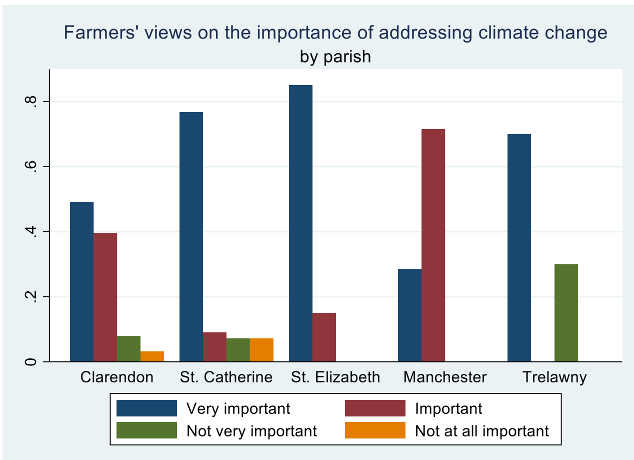

Figure 2.9 Farmers Responses on the Important of Addressing Climate Change.

In Figure 2.10, we also see the percent of farmers within each parish perceiving climate risk on their livestock. As shown, except for Manchester, for a farmer at least 80% of their peers within a 10km radius have perceive climate change effects on their livestock production.

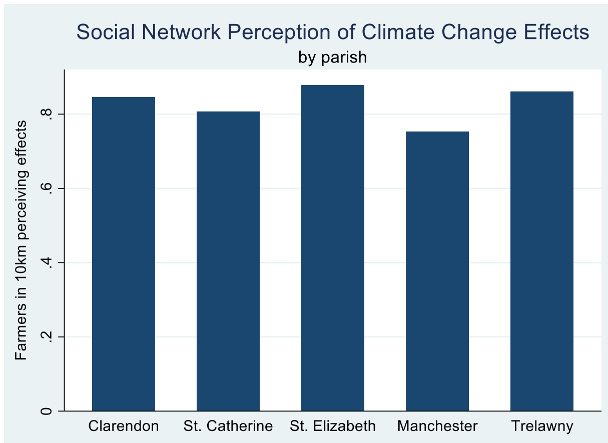

Figure 2.10 Percent of Farmers Within a 10km radius Perceiving Climate Change Effects on Livestock.

Table 2.6. summarizes the information provided by farmers on how often they follow changes in climate parameters, the main medium of climate change information, and the causes of climate change.

Table 2.6
Weather Check, Medium of Hearing About Climate Change, and Responsible Causes.

Variable	Obs.	Mean	Variable	Obs.	Mean
Daily check	167	0.533	Human activities	156	0.321
Weekly check	167	0.054	Natural activities	156	0.212
Random check	167	0.240	Both human and natural factors	156	0.455
Never	167	0.174	Neither human nor natural factors	156	0.013
Television	156	0.910			
Radio	156	0.577			
Newspaper	156	0.359			
Friends/Family	156	0.468			
Internet	156	0.256			
Government	156	0.282			

This table shows the percent of farmers and their frequency of checking the weather. I also show the percent of farmers and the medium through which they have heard about climate change and the responsible causes.

We observe that 53.3% of farmers follow weather information daily while 24% of farmers randomly watch the weather report[7]. An overwhelming majority (91%) of farmers get their information about climate change from television while information from government (28.2%) and the internet (25.2%) are the two lowest respectively. When asked about the causes of climate change effects, 1.3% of farmers indicated that it is not due to human or natural activities. In contrast, 45.5% indicated that both natural and human activities lead to climate change. In Figure 2.11, we see no farmer in Manchester keeping a daily update on meteorological conditions.

[7] A challenge with keeping up with the weather report in Jamaica is that it is aired at only specific times. It is common for Jamaicans to only watch the local TV stations. There are two such stations, Television Jamaica (TVJ) and CVM TV. It is common for the weather report to be aired nightly around 8 pm for TVJ and 9 pm CVM TV; it is the last segment of the news report. This may be one of the reasons the lower than expected monitoring of weather conditions. In addition, it is not uncommon for farmers to be absent from home during the daytime, which would likely cause them to miss any weather report during the day. This finding potential indicate those farmers who have an interest in weather conditions and how it would affect their production.

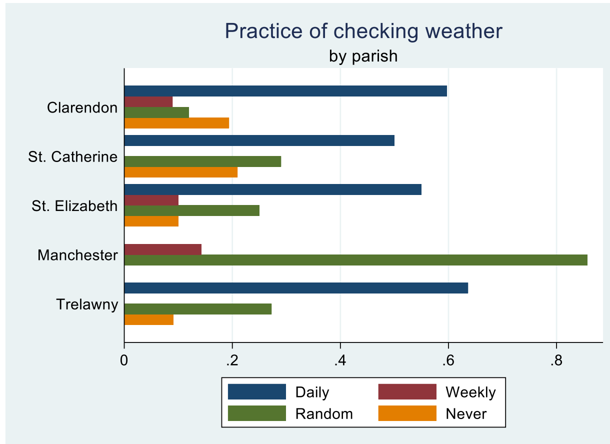

Figure 2.11 Farmers Frequency of Keeping up With Climatic Conditions.

On a parish basis, Figure 2.12 shows Manchester farmers were the highest percent to indicate climate change effects are attributed to human activities while the lowest percent of farmers to indicate the same are from St. Catherine.

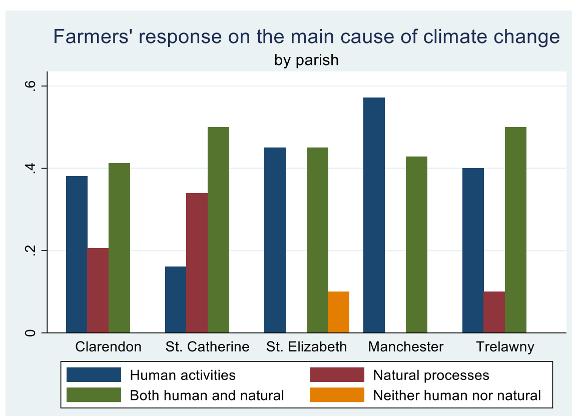

Figure 2.12 Farmers' Views on the Main Causes of Climate Change.

Figure 2.12 also highlight that only farmers in St. Elizabeth indicate that climate change is not caused by human and natural activities.

Table 2.7 summarizes the main environmental concerns and livestock issues for farmers. The highest percent (38.3%) of farmers indicated flooding was the most serious concern. This was followed by droughts at 27.5%.

Table 2.7
Main Environmental Concern and Livestock Health Issues.

Variable	Obs.	Mean	Variable	Obs.	Mean
Water pollution	167	0.060	Worms	167	0.575
Flooding	167	0.383	Disease	167	0.156
Drought	167	0.275	Diarrhea	167	0.329
Temperature	167	0.048	Bloating	167	0.054
Hurricanes	167	0.072	Lost appetite	167	0.024
None	167	0.162	Parasite	167	0.162
			None	167	0.174
			Other	167	0.287

This table shows the percent of farmers and their indication of the main environmental concern and livestock health issues they face.

The main health concerns were worms (57.5%) and diarrhea (32.9%). In Figure 13, we see that flooding is the main concern for Clarendon farmers, but Manchester farmers are more concerned about hurricanes.

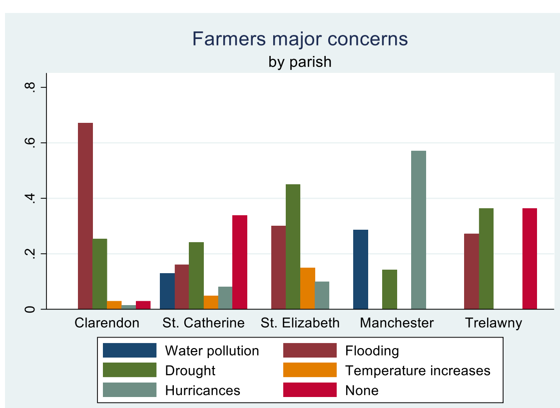

Figure 2.13 Major Environmental Concerns for Farmers.

In Table 2.8, summary statistics are presented for farmers' observation of rainfall, heat, and hurricane patterns.

Table 2.8
Rainfall Patterns, Hurricane Patterns, and Heat Patterns.

Variable	Obs.	Mean	Variable	Obs.	Mean
Change in rainfall pattern	167	0.946	Hot days pattern	167	0.904
More rain	158	0.076	Increase in hot days	151	0.874
Less rain	158	0.462	Decrease in hot days	151	0.013
Unpredictable	158	0.462	Fluctuation in hot days	151	0.113
Hurricane patterns	167	0.725	Heat intensity	167	0.946
Decrease in hurricanes	121	0.512	Decrease in heat intensity	158	0.032
Increase in hurricanes	121	0.372	Increase in heat intensity	158	0.968
More severe hurricanes	121	0.116			

This table shows the percent of farmers who have indicate a change in long-term rainfall pattern and the perceived changed. I also show the percent of farmers who have observed changes in heat and hurricane patterns.

The table shows that 94.6% of farmers have observed changes in rainfall patterns over their lifetime. Among those, 46.2% of farmers indicated less rainfall and unpredictable changes in rainfall patterns. For extreme storms, 72.5% affirmed that hurricane patterns have changed, 51% of which indicated this was a decrease in the occurrence of hurricanes. When asked, 90% of farmers indicated that they have observed changes in heat patterns and 94.6% indicated changes in heat intensity. Approximately 87.4% of farmers indicated that the specific change of heat pattern was increases in the number of hot days. Among those who observe changes in the intensity of heat, 96.8% indicated increased intensity of heat.

2.4. Results

This section presents the results from the econometric analysis. In subsection 2.4.1. I present the results from estimating two probit regression models. The first is a probit model with the binary outcome of whether farmers perceive climate change-related effects on their production or not and the second probit model shows the results from estimating the model with the binary outcome of whether farmers chose any (adaptive) measure to mitigate the effects of climate change-related events on their production.

2.4.1. Probit Regression Results

Probit regression results are presented in Tables 2.9 and 2.10. Table 2.9 shows the probit regression estimates and marginal effects of factors that affect farmers' awareness of climate change-related extreme events on their livestock. In columns (1) and (2) I proxy for farm size by using the total number of workers on the farm while for columns (3) and (4) I use the total number of livestock on the farm. The marginal effects are reported in columns (2) and (4). We observe from columns (1) and (2) that social networks[8], household head's education, and farm size have a significant impact on farmer's perception. In this table I present also the first measure of social networks.

[8] In this study, I include two measures of social networks (1) the percent of farmers within a 10km who have experienced climate change-related effects on their production; and (2) the percent of farmers within a 10km radius who utilize adaptive measures in response to climate change-related events. Though this does not explicitly capture any actual personal connections, it does indicate the potential to do so.

Table 2.9

Probit Regression of Factors That Influence Whether Farmers Detect Climate Change-Related Effects on Their Production.

Variables	(1) Perceive	(2) Perceive (M.E.)	(3) Perceive	(4) Perceive (M.E.)
Social network (% perceiving)	8.309***	0.456*	6.595***	0.944***
	(2.132)	(0.243)	(1.711)	(0.252)
Number of workers	1.050***	0.058**		
	(0.304)	(0.026)		
Total livestock			0.00309	0.0004
			(0.00383)	(0.0005)
Eastern parish	-0.0767	-0.004	0.487	0.070
	(0.470)	(0.025)	(0.377)	(0.053)
Household head education	-1.182***	-0.065*	-0.535	-0.077
	(0.414)	(0.035)	(0.326)	(0.048)
Household head age	-0.0426***	-0.002	-0.0417***	-0.006***
	(0.0152)	(0.001)	(0.0133)	(0.002)
Household head gender	-0.0150	-0.001	-0.298	-0.043
	(0.455)	(0.025)	(0.417)	(0.060)
Heard of climate change	0.481	0.026	0.187	0.027
	(0.750)	(0.043)	(0.643)	(0.092)
Household size	0.0251	0.001	0.206**	0.029*
	(0.112)	(0.006)	(0.103)	(0.015)
Wealth index	1.062	0.058	0.316	0.045
	(0.715)	(0.047)	(0.531)	(0.075)
Constant	-6.343**		-3.304*	
	(2.472)		(1.892)	
Observations	157	157	157	157

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.

This table shows the probit regression of factors that influence whether farmers perceive effects of climate change-related extreme events on their production. The dependent variable is binary where 1 indicates that farmers do perceive effects of climate change-related extreme events on their production. Columns (1) and (3) show the unadjusted estimates of the probit regression, while columns (2) and (4) show the marginal effects of the variables.

In Table 2.9, the social networks variable measures the percent of farmers in a 10km radius who have detected climate change-related effects on their production. As shown in column (2) the effect of social networks on the probability of perceiving climate change-related events on livestock production is positive. A 10% increase leads to a 4.6% increase in the likelihood of a farmer perceiving climate change-related effects. In column (4), with the total number of livestock proxying for farm size, the results indicate that a 10% increase in the percent of farmers becoming aware of climate change effects on their production leads to a 9.4% increase in the likelihood a farmer will also perceive such effects.

In column (2) we see that farm size positively impacts farmer's perception of climate change-related effects. An increase in an additional worker leads to farmers' likelihood of perceiving climate change-related effects increasing by 5.8%. However, we observe that farmers who have completed at least high school are less likely to perceive the effects of climate change on their production. We also see from the results in column (4) that a 10-year increase in the household head's age is associated with a 6% decrease in the likelihood of perceiving climate change-related effects on livestock. The size of the household has a positive effect on farmers' ability to perceive climate change effects. An additional person in the household is associated with an increase in perceiving the effects of climate change by 2.9%.

Table 2.10 presents the probit regression results for whether farmers have taken adaptive strategies against perceived effects of climate change-related events on their livestock. The marginal effects of the estimates are reported in columns (2) and (4). For columns (1) and (2) the number of workers is the first measure of farm size. We observe positive and statistically significant results for social networks, household head's education, parish location, and the number of workers. In this table, the social networks variable is measured as the percent of farmers in a 10km radius that choose some measure to mitigate the effects of climate change-related events on their production. Looking at column (2), which takes the number of workers as a proxy for farm size, we see several variables impacting the probability of adaptation.

Table 2.10
Probit Regression of Factors Influencing Whether Farmers Chose Adaptive Strategies.

VARIABLES	(1) Adapt	(2) Adapt (M.E.)	(3) Adapt	(4) Adapt (M.E.)
Social network (% adapting)	6.328***	1.695***	5.570***	1.570***
	(1.600)	(0.396)	(1.374)	(0.373)
Number of workers	0.551***	0.148***		
	(0.140)	(0.037)		
Total livestock			0.0136***	0.004***
			(0.00444)	(0.001)
Eastern parish	1.140***	0.305***	1.236***	0.349***
	(0.387)	(0.108)	(0.377)	(0.111)
Household head education	1.259***	0.337***	1.078***	0.304***
	(0.336)	(0.093)	(0.325)	(0.093)
Household head age	0.0184	0.005	0.0180	0.005
	(0.0128)	(0.003)	(0.0123)	(0.003)
Household head gender	0.505	0.135	0.549	0.155
	(0.399)	(0.107)	(0.399)	(0.112)
Heard of climate change	0.529	0.142	0.295	0.083
	(0.562)	(0.152)	(0.573)	(0.163)
Household size	-0.134	-0.036	0.0477	0.013
	(0.0939)	(0.025)	(0.0926)	(0.026)
Wealth index	-1.400**	-0.375**	-1.655***	-0.467***
	(0.590)	(0.152)	(0.557)	(0.155)
Constant	-5.202***		-4.059***	
	(1.661)		(1.456)	
Observations	133	133	133	133

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

This table shows the probit regression of factors that impact farmers decision to choose adaptive strategies against the effects of the climate change-related events. In columns (1) and (3) I report the unadjusted estimates of the probit regression and in columns (2) and (4) I report the marginal effects of the estimates.

An increase in the percent of farmers within a social network that adapt leads to a 1.7% increase in a farmer's likelihood to take adaptive measures. In column (2) we see that farm size has positive and statistically significant impact on the likelihood of adaptation. For an additional worker on the farm, the likelihood of adaptation increases by 14.8%. Farmers in the eastern parishes are also 30.5% more likely to engage in adaptive measures than farmers from western parishes. We also see that farmers who have completed at least high school are 33.7% more likely to take adaptive measures than those with education below high school.

In column (4) we see a similar effect when I estimate the probit adaptation model. First, we see the effect of the social networks variable has a positive impact on the probability of adaptation. An increase in the percent of neighboring farmers taking adaptive measures increases the likelihood of a farmer adapting by 1.6%. We also see that the alternative proxy for farm size has a positive and statistically significant impact on adaptation. An additional 10 livestock holdings increase the probability of adaptation by 4%. Farmers in eastern parishes are 35% more likely to take adaptive measures against climate change-related events relative to farmers in other parishes. We also see that farmers who have attained at least high school education are 30.4% more likely to take adaptive measures compared to those whose educational qualification are below that of high school.

2.4.2. Heckman Probit Model

Table 2.11
Heckman Probit Model Results

Variables	(1) Perceive	(2) Adapt	(3) M.E.	(4) Perceive	(5) Adapt	(6) M.E.
Social network (% adapting)		5.976***	1.522***		4.939***	1.269***
		(1.173)	(0.309)		(1.052)	(0.266)
Social network (% perceiving)	8.239***			6.558***		
	(1.461)			(1.258)		
Number of workers	0.978***	0.427***	0.109***			
	(0.316)	(0.156)	(0.038)			
Total livestock				0.004	0.013***	0.003***
				(0.004)	(0.004)	(0.001)
Eastern parish	-0.085	0.996***	0.254***	0.614*	1.088***	0.279***
	(0.493)	(0.385)	(0.092)	(0.338)	(0.315)	(0.074)
Household head's education	-1.059***	1.238***	0.315***	-0.443	1.009***	0.259***
	(0.350)	(0.360)	(0.087)	(0.282)	(0.319)	(0.078)
Household head's age	-0.045**	0.023*	0.006*	-0.044***	0.023*	0.006*
	(0.019)	(0.014)	(0.003)	(0.015)	(0.013)	(0.003)
Household head's gender	-0.111	0.560	0.143	-0.362	0.618	0.159
	(0.490)	(0.438)	0.108	(0.381)	(0.446)	(0.111)
Heard of climate change	0.596	0.580	0.148	0.414	0.293	0.075
	(0.562)	(0.401)	(0.100)	(0.422)	(0.373)	(0.095)
Household size	0.065	-0.112	-0.029	0.249**	0.023	0.006
	(0.106)	(0.0845)	(0.022)	(0.112)	(0.099)	(0.025)
Wealth index	1.267**	-1.351***	-0.344***	0.158	-1.476***	-0.379***
	(0.505)	(0.420)	(0.108)	(0.370)	(0.409)	(0.106)
Constant	-6.645***	-4.921***		-3.486**	-3.769***	
	(2.232)	(1.441)		(1.699)	(1.311)	
Observations	157	157	156	157	157	156

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 2.11 shows the results for the Heckman probit model[9]. The estimates from Table 2.11 show that farmers adaption decisions are influenced by several factors. In columns (1), (2), and (3) I report the results for the model with the total number of workers as a measure for farm size. In columns (4), (5), and (6) I report the results for the model with the total number of livestock as a proxy for farm size. In columns (3) and (6) I report the marginal effects of adaptation for each model specification. The models show the importance of several variables on the probability of adaptation. As shown in column (3) social networks, farm size, farmer's location, and education have a positive and statistically significant impact on the likelihood of adaptation. In column (3), the results show that for a one percent increase in neighboring farmers utilizing adaptative measures against climate change-related events, the likelihood of adaptation increases by 1.5%. In column (3) we see an additional worker increases the probability of adaptation by 10.9%. We also see that farmers in eastern parishes are 25% more likely to utilize adaptive measures relative to farmers not in eastern parishes. We also see that farmers with at least high education are 31.5% more likely to take adaptive measures compared to farmers who have not attained high school education.

In column (6), when I include the total livestock holdings, we see a similar effect. A one percent increase in neighboring farmers taking adaptive measures increases the likelihood of adaptation by 1.3%. Here an increase in livestock holdings by 10 leads to a 3% increase in farmers likelihood of taking adaptive measures against climate change-related events. We again see the positive effect of farmers' location on the likelihood of adaptation. Farmers in the eastern parishes are 28% more likely to take adaptive measures compared to farmers not in eastern parishes. Similarly, the educational attainment of farmers plays a crucial role on adaptation here. For farmers

[9] An analysis using the limited dependent variable model was carried out. The results (not presented here) are consistent with those of the probit and Heckman probit models.

with at least high school education, their likelihood of adaptation is 26% more than those farmers who have not attained high school educational qualifications.

Overall, the results here indicate that the percent increase in neighboring farmers detecting climate change-related effects on their production positively influence the likelihood of farmers becoming aware of similar effects on their production. Similarly, the likelihood of adaptation increases for a one percent increase in neighboring farmers taking some adaptive strategy. For those farmers who have detected climate change-related events we see farm size, farmers' location, and educational attainment are important characteristics for farmers that can be vital for policymakers who intend on stimulating greater climate actions among farmers.

2.5. Conclusion

This paper investigated the factors that influence Jamaican livestock farmers perceiving climate change-related effects on their production and adaptive strategies. Specifically, I examined the role of farmers' social networks, farm size, and location on their climate perception risks and their adaptation practices. Social networks in this paper was in two forms: (1) the percent of farmers within a 10km radius who indicated they detected climate change-related effects on their production; and (2) the percent of farmers within a 10km radius who indicated they have chosen some measure to mitigate the impact of climate change-related events on their production. Social networks highlight the magnitude and significance of outside influence on farmers' decision making. Through the diffusion of knowledge, social networks can play a crucial role to improve agricultural best practices and reducing misinformation. In the presence of climate change, farmers' communication about how climate change-related events impact their production to others may influence their risk perceptions. Social networks could be the channel through which information about detecting climate change-related effects on production can be disseminated. By social networks positively impacting the likelihood of perceiving climate change-related effects, a farmer may then be able to adapt. In addition, this study indicates that through neighboring farmers practicing adaptive measures, a farmer's likelihood of adaptation increases.

There are several findings of this study that may be helpful for policymakers considering action on climate change. First, this study highlights the importance of social networks. This study also highlights that although it would be the first best solution to reach all farmers, in cases where that is difficult, for example, due to poor infrastructure, the second-best solution is to reach a targeted social network. Given those challenges, policymakers who intend on improving climate change education particularly for perception and adaptation can start by identifying social network points where despite not physically communicating with far-to-reach farmers, the information can still be transmitted to those areas. This is because communication about production experience and the level or credibility or trust among farmers is high. As this study indicates, this leads to greater likelihood of perceiving the risk to production which is a crucial step for taking adaptive strategies.

A second finding of this study is the role of farm size and location for the likelihood of adaption. This study shows that large farm size has a positive effect on perceiving climate change-related effects on production and the likelihood to take adaptive measures. Farmers who operate in eastern parishes, St. Catherine and Clarendon, are more likely to perceive the effect of climate change-related events and adopt measures to mitigate the effects of such events. The finding highlights the potential inequalities that exists in the agriculture sector and again provides an avenue for what policymakers can do to address the non-uniformity of climate action. This also demonstrates to policymakers a target group for disseminating climate action information if Jamaica's agricultural sector is to be robust against the effects of climate change-related events.

Other findings coming from this study are that while most farmers have heard of climate change and do have a moderate idea of its main causes and who stands to be impacted, there is variation in their detection of climate change-related events on their production and responses. In particular, farmers have largely detected flooding and drought effects on their livestock compared to heat effects and they are mainly responsive to floods and droughts. However, their response of making changes to the pens in relation to flood and changing where the animals feed for droughts may not be sustainable. This presents greater opportunities for technological innovation and adoption methods that farmers can utilize to ensure that over the long term, their livestock production is not depleted due to floods and droughts. Rather, farmers may benefit from more flood-proof pens and veterinary treatments that may reduce the likely adverse effects from flooding. In addition, in times of droughts, being able to identify alternative nutrient-rich feed for animals may prove beneficial for farmers. These implementation methods could sustain both the income source of farmers and the agriculture sector for Jamaica.

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CHAPTER 3

THE EFFECTS OF CLIMATE CHANGE-RELATED EXTREME EVENTS ON MIGRATION TO THE US

3.1. Introduction

The global economic costs of natural disasters are estimated to be approximately $520 billion each year, resulting in lower household consumption and leaving more households vulnerable to poverty (World Bank, 2020). This cost is a greater burden for low- and middle-income countries. Damage to power generation and transport infrastructure alone cost low-and-middle income countries $18 billion per year (World Bank, 2020). Since World War II, natural disasters have been a greater driver of migration than conflict (Gurumurthy & Gordon, 2019). In addition, storms have resulted in significant loss of economic resources and millions of dollars in losses for insurance companies (Insurance Information Institute, 2019). In this paper, I estimate the effect of climate change-related extreme events on migration flows from foreign territories to the United States.

Climate change is likely to increase the frequency and intensity of storms and other extreme events (Gurumurthy & Gordon, 2019; Strobl, 2011). The World Bank predicts that climate change will lead to as many as 140 million people moving internally by 2050 (Gurumurthy & Gordon, 2019). [10] For natural disasters specifically, Gurumurthy & Gordon (2019) suggest that both internal and international migration are likely to be intensified. By affecting migration flows, climate change extreme events may have serious economic consequences for both the migrant-

[10] Estimates also suggest that between 2008 and 2015, natural disasters resulted in the internal displacement of 26 million people per year.

sending countries and migrant-receiving countries. It is therefore critical that we understand how extreme events likely to increase with climate change affect migration patterns.

The purpose of this paper is to estimate the effect of extreme weather events, which are negative economic shocks, on migration to the US. Because of the potentially enormous danger and economic impact of extreme events, some individuals are likely to relocate (Strobl, 2011). However, the impact of extreme weather events on migration is ambiguous for several reasons. First, extreme events may not have an impact on migration if households simply cannot afford to relocate. That is, if extreme events do not affect migration costs, then the impact would be positive as we expect people to migrate. However, if migration costs are affected, then we expect that, in our case, international migration to decrease as a result of climate change-related extreme events. Individuals or countries that possess the necessary resources to buffer against extreme weather events will not be significantly impacted. Second, extreme events may increase migration rates if households can relocate to other regions due to social networks (or connections) and favorable immigration policies. Of course, if we consider the type of migration the impact on international versus internal migration can be different. Households that relocate internally may not possess necessary resources that cover migration cost for travel abroad. In such cases, extreme weather events lead to an increase in internal migration rate but no impact on international migration. Finally, the impact of extreme events on migration may depend on the form of damage and for that reason the effect may be ambiguous. For example, individuals' migration decisions may depend on the pecuniary, non-pecuniary, or cumulative damage of extreme events. In addition, migration is sometimes not immediate and therefore it becomes important to understand whether extreme events in the past could still lead to changes in migration flows.

I investigate the impact of extreme weather events on migration flows to the United States using data from the US Department of State – Bureau of Consular Affairs, The International Disaster Database (EM-DAT), and World Bank's World Development Indicator database. This paper contributes to the literature by looking at the effect of climate change-related events on legal migration flows to the United States and estimating the relationship using lag effects which are more consistent with the actual immigration process (Bier, 2019).

I find that the effects are heterogenous across measures of the extreme events. This study shows that when measured with a two-years lag, monetary damages from floods and droughts decrease migration. Floods and droughts lead to a decline in migration inflow to the US of 6 and 2 per 100,000 of the home-country population or 20% and 7% of the sample average, respectively. Additionally, the results of this study indicate that migration is more responsive to the type of extreme event rather than the cumulative monetary damage or the cumulative human impact.

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3.2. Literature Review

There are multiple reasons people choose to migrate. Some families migrate within and across borders in economic pursuits. Stark & Bloom's (1985) prominent paper argues that individuals or households migrate whenever there is a perceived greater return to their skill levels or "reference group". For some immigrants, migration is a way to diversify risk and increase their welfare (Stark & Bloom, 1985). Paat (2013) summarizes the motives for migration into three categories. The first motive for migration is economic assistance. Here Paat (2013) reiterates what the economic literature has studied for years; when the benefits of migrating is greater than migration costs then emigration is more likely to occur. The aspiration to improve their way of life serves as an incentive for people to apply for work visa or student visa prior to employment visas. People may migrate to gain a greater level of human capital knowledge and/or find work which complements their productivity levels or yield higher returns than their country of origin.

Family reunification is another motivation for migration. Immigrants may long to be with their social support system and thus desire to join their families. This process has historically been facilitated through United States immigration policies giving preferential treatment to spouses, parents, and children. Immigrants may long for social support which motivates them to relocate to a community where their ethnic group is more concentrated (Paat, 2013).

A third motivation for migration is political reasons. War, oppression, persecution, and other sources of conflict have resulted in migration. Paat (2013) states this is one of the main sources of migration. Refugees try to escape catastrophic events in search of asylum in other countries such as the United States. The current United States immigration policy offers refugees the chance to gain permanent residency after a year of entering the country (Paat, 2013). While Paat (2013) highlights three important channels through which migration occurs, the paper neglects to comment on the impact of environmental factors which in recent times have overtaken cross-country movement caused by conflict (Gurumurthy & Gordon, 2019).

Economic studies have looked at the various effects of climate change on economic growth. Nordhaus (2010) examines the impact of hurricane and global warming on economic activity in the US. The results show that the economic costs of hurricanes can be substantial, amounting to billions of dollars. Strobl (2011) uses a destruction index derived from the monetary loss equation to estimate the impact of hurricanes on coastal counties in the United States. The results suggest that economic growth is depressed by at least 0.45 percentage points. Strobl (2011) results also show that approximately 28% of growth losses are derived from more wealthy households migrating; highlighting the linkage between migration and economic prosperity. Boustan et al. (2017) use new data on natural disasters to examine its impact on economic activity in US counties. As a result of severe disasters, affected counties in the US experience greater emigration rates, declines in house prices, and higher levels of poverty.

Other studies approach the economic effects of climate change differently. Cattaneo & Peri (2016) investigate how temperature affects international and internal migration over four decades. They argue some countries will experience a disproportionate effect of climate change on agricultural productivity, food security, and health. This serves as a push factor for migration. In the agricultural sector, for example, Cattaneo & Peri (2016) find that optimal yields occur at 14°C and decline once the temperature is higher. Farmers may respond by either reducing their farming activities and shifting to other sectors or migrating to cooler areas. Founded on the Roy-Borjas model, Cattaneo & Peri (2016) hypothesized that increases in temperature will decrease the income in rural areas of poor countries and so reduce migration rates. On the other hand, temperature increases may push individuals, who are residents of middle-income countries to emigrate. Their results indicate no significant effect of temperature on migration rates in their linear model. However, they find temperature increases for middle income countries raise emigration rates while for poor countries, emigration rates are negative.

One of the main outcomes for climate change is the depletion of natural resources and the damage of assets such as houses (Black et al., 2011). That effect exacerbates out-migration. Using a gravity model, Backhaus et al. (2015) examine how well climatic variability affect bilateral migration. Backhaus et al. (2015) find an increase in average temperature results in 1,301 additional migrants per year and for an increase in average precipitation, migration is expected to increase by 753 per year. Overall, their results signal that climate change leads to a moderate increase in migration. This also applies to countries which are largely dependent on agricultural production.

Drabo & Mbaye (2015) investigate the impact of climate change on migration of educated individuals. Their fixed effects model shows that natural disasters have a positive impact on the migration of educated individuals. More detailed analysis shows, however, that much of this effect is attributed to hydrological disasters such as droughts and floods. Drabo & Mbaye (2015) use a dummy for natural disasters if the country in question has experienced any storms, drought, flood, wildfire, and extreme temperature in the past five years. However, doing this does not allow them to capture the severity of these effects which can induce migration.

Drabo & Mbaye (2015) and Piguet et al. (2011) suggest migration of highly skilled individuals may act as a failure strategy and an adaptive strategy. Drabo & Mbaye (2015) state that migration becomes a failure strategy for countries when migrants with higher human capital leave their countries of origin with lower actual financial and human resource development. The positive aspect of this brain drain effect is, it is seen as a potential adaptive strategy. Here the highly skilled may remit, which can help cover the cost of the brain drain or buffer against exogenous shocks. Drabo & Mbaye (2015), however, does not take into consideration the role of remittances, a non-labor income that may help the affected overcome the cost of extreme events.

A final relevant link through which climate change and migration has being examined is the conflict channel. According to Bosetti et al. (2018) temperature increases can make life more difficult for some regions. This sets off a flow of migrants who may then compete for resources elsewhere, which may lead to conflicts. However, Bosetti et al. (2018) find no clear evidence that migration is due to climate change impacts on conflict in destination countries.

3.3. Data and Descriptive Statistics

In this paper I investigate the effect of climate change-related extreme weather events on migration to the United States. To estimate this relationship, I draw on data from several sources. First, the primary migration data I use in this paper are from the US Department of State – Bureau of Consular Affairs which provides yearly visa statistics on visa issuances by consular offices in foreign states. This data covers 19 years of legal migration to the United States. I match this country of origin migration data with country of origin extreme weather events and macroeconomic indicators. This leaves a panel of 196 countries for the Department of State data[11]. The Department of State immigration data provides an official record of legal immigration within a year and is therefore unlikely to be affected by attrition from death or return migration (Mahajan & Yang, 2020). These data indicate migrants' country of origin and the class in which they are granted admission. The Department of State data do not provide information on whether inflows are new or if migrants have simply change the status of their residence from temporary to permanent (Mahajan & Yang, 2020).

Summary statistics of the migration data from the US Department of State are shown in Tables 3.1 and 3.2 for all countries and low-and-middle income countries respectively.

[11] Appendix B shows the list the sample of all countries.

Table 3.1

Summary Statistics for all Countries in the Department of State Sample (pooled across years)

Variable	Obs.	Mean	Std. Dev.	Min	Max
Panel A: Dependent variable and control variables					
Migrants (per 100,000)	3,652	30.41	88.00	0.00	1,127.30
GDP per capita	3,456	13,916.00	21,558.00	194.00	193,746.00
Population growth (%)	3,717	1.47	1.55	-9.08	17.51
Agriculture (% GDP)	3,331	11.65	11.61	0.02	79.04
Remittances (% GDP)	3,044	4.64	6.91	0.00	53.83
Political stability	2,957	0.05	0.21	0.00	1.00
Panel B: Storm Information					
Storm damage (% GDP)	3,456	0.27	6.27	0.00	320.72
Storm affected (% pop.)	3,716	0.38	3.88	0.00	99.99
Storm frequency	4,028	0.40	1.25	0.00	17.00
Panel C: Flood Information					
Flood damage (% GDP)	3,456	0.06	0.66	0.00	25.84
Flood affected (% pop.)	3,717	0.34	1.79	0.00	36.83
Flood frequency	4,028	0.68	1.49	0.00	20.00
Panel D: Drought Information					
Drought damage (% GDP)	3,456	0.01	0.18	0.00	6.34
Drought affected (% pop.)	3,717	0.60	4.13	0.00	90.55
Drought frequency	4,028	0.07	0.28	0.00	3.00
Extreme Temperature Information					
Extr. Temp. damage (% GDP)	3,456	0.01	0.30	0.00	16.47
Extr. Temp. affected (% pop.)	3,717	0.10	2.16	0.00	80.00
Extr. Temp. frequency	4,028	0.02	0.23	0.00	5.00

Note: This table shows the summary statistics for all variables employed in the analysis of the impact of climate change-related extreme events on migration to the US. Specifically, this table summarizes the information for all countries included in the sample. In Panel A, there is the summary of the migration per 100,000 of home-country population and the control variables. In Panel B to E are storm, flood, drought, and extreme temperature summary statistics. The migration data is obtained from the US Department of State – Bureau of Consular Affairs and climate change-related extreme events data are obtained from the International Disaster Database.

Table 3.2

Summary Statistics for Low- and Middle-Income Countries in the Department of State Sample (pooled across years)

Variable	Obs.	Mean	Std. Dev.	Min	Max
Panel A: Dependent variable and control variables					
Migrants (per 100,000)	2,407	35.99	98.59	0.00	1,127.30
GDP per capita	2,441	3,602.00	3,091.00	195.00	12,346.00
Population growth (%)	2,441	1.55	1.27	-9.08	9.11
Agriculture (% GDP)	2,320	15.76	11.58	1.29	79.04
Remittances (% GDP)	2,190	5.98	7.61	0.00	53.83
Political stability	2,000	0.05	0.23	0.00	1.00
Panel B: Storm Information					
Storm damage (% GDP)	2,441	0.35	7.43	0.00	320.72
Storm affected (% pop.)	2,440	0.53	4.68	0.00	99.99
Storm frequency	2,441	0.47	1.45	0.00	17.00
Panel C: Flood Information					
Flood damage (% GDP)	2,441	0.08	0.78	0.00	25.84
Flood affected (% pop.)	2,441	0.47	2.15	0.00	36.83
Flood frequency	2,441	0.95	1.78	0.00	20.00
Panel D: Drought Information					
Drought damage (% GDP)	2,441	0.02	0.21	0.00	6.34
Drought affected (% pop.)	2,441	0.78	4.58	0.00	90.55
Drought frequency	2,441	0.10	0.33	0.00	3.00
Extreme Temperature Information					
Extr. Temp. damage (% GDP)	2,441	0.01	0.35	0.00	16.47
Extr. Temp. affected (% pop.)	2,441	0.16	2.66	0.00	80.00
Extr. Temp. frequency	2,441	0.04	0.28	0.00	5.00

Note: This table shows the summary statistics for all variables employed in the analysis of the impact of climate change-related extreme events on migration to the US. Specifically, this table summarizes the information for low- and middle-income countries included in the sample. In Panel A, there is the summary of the migration per 100,000 of home-country population and the control variables. In Panel B to E are storm, flood, drought, and extreme temperature summary statistics. The migration data is obtained from the US Department of State – Bureau of Consular Affairs and climate change-related extreme events data are obtained from the International Disaster Database.

These summary statistics show for low-and-middle income countries, the average immigration to the US is higher, approximately 35 per 100,000 of the home-country population. Comparing the panels of Tables 3.1 and 3.2, we see that for all panels, the averages for the monetary damage, human impact, and frequency of the climate change-related natural disasters are higher for low-and-middle income countries. In addition, we observe that storm damage costs on average more in terms of GDP, but droughts affect a higher percent of the population.

The second source of data comes from the International Disaster database. This database provides information on all types of disasters and the countries impacted. From this source, I utilize information on climate change-related extreme events and link that with the countries for which I have migration data. The sample period covers the years 2000 to 2018. In this paper, my focus is on climate change-related extreme events: storms, floods, droughts, and extreme temperature. For each type, I used the data on their monetary damage, number of lives affected, and time of occurrence. I also compute the frequency of each type of extreme weather event and the duration. The monetary damage of storms, floods, droughts, and extreme temperature is defined as the pecuniary cost of the extreme events in USD as a one percent of GDP. The pecuniary cost is the estimated damage of property, crops, and livestock. The measure for the number of lives affected by storms, floods, droughts, and extreme temperature is the human impact of the extreme events as a one percent of the home-country population size. The human impact is the sum of the total deaths and people requiring immediate assistance due to the extreme event. The cumulative measure of monetary damage is the sum of the monetary damage for storms, floods, droughts, and extreme temperature. Similarly, the cumulative number of lives affected is the sum of the number of lives affected by storms, floods, droughts, and extreme temperature. The frequency of storms, floods, droughts, and extreme temperature is the number of occurrences in the home-country. The duration for storms, floods, droughts, and extreme temperature is the number of days each of the extreme events lasts. This is computed using the start and end date of the extreme events.

3.4. Empirical Strategy

I test the effect of climate change-related extreme events on migration inflows to the United States using two specifications:

$$M_{it} = \alpha_0 + \boldsymbol{D'}_{\boldsymbol{it-s}}\boldsymbol{\alpha_1} + \boldsymbol{X'}_{\boldsymbol{it}}\boldsymbol{\alpha_2} + \delta_i + \omega_t + \phi_i t + \varepsilon_{it} \qquad (3.1)$$

$$M_{it} = \alpha_0 + \boldsymbol{D'}_{\boldsymbol{it}}\boldsymbol{\alpha_1} + \boldsymbol{X'}_{\boldsymbol{it}}\boldsymbol{\alpha_2} + \delta_i + \omega_t + \phi_i t + \varepsilon_{it} \qquad (3.2)$$

In the above, M_{it} represents the number of migrants from country of origin i to the US in year t as a proportion of population per 100,000. The sample period t runs from 2000 to 2018. Our coefficient of interest α_1 reflects the effect of climate change-related extreme events on migration per 100,000 of the home-country population. The vector $\boldsymbol{D_{it}}$ denotes monetary damage (% GDP), and the number of lives affected (% home-country population), cumulative measures of pecuniary and non-pecuniary damage, frequency, and duration of storms, floods, droughts, and extreme temperature. In this study, these variables indicate how extreme weather events affect countries economic growth and development by asset and personal losses. These losses for foreign residents are likely to increase the benefits of migrating to the US. Equation (3.1) shows the lagged effects of the variables of interest. I take the lagged effects of the natural disasters due to the plausibility that they do not lead to an immediate emigration from the country of origin to the US. It is well-known that the immigration process system faces backlogs and so legal immigration to the US can take years. Following the average waiting time for visa reported by Bier (2019) I estimate the effect of 2 and 3 years lag. In addition to equation (3.1) I estimate the model using 4 years lags. As equation (3.2) shows, I examine an alternative specification without lag effects.

The vector X denotes the inclusion of control variables. The control variables are GDP per capita, population growth rate, agriculture output (% GDP), remittances (% GDP), and political stability, I also include combined measures of the monetary damage and human impact of the extreme events.

The term ω_t represents year fixed-effects dummies, δ_i represents country of origin fixed effects, $\phi_i t$ captures the linear trend in immigration to the US from foreign territories i, and ε_{it} is assumed to be a random error term. I include the country of origin fixed effects as a control for circumstances, such as distance, that will affect the probability of residents from country of origin i to migrate to the United States. The year fixed effects control for time-invariant factors that influence the ability of residents from country of origin i to migrate to the United States.

The predicted effect of climate change-related natural disasters on migration is ambiguous if it affects migration costs (Mahajan & Yang, 2020). To understand this, consider that individuals must cover some fixed cost in order to migrate. In our case if the climate change-related extreme events do not affect migration costs then we can expect migration to the United States to increase. That is, $\boldsymbol{\alpha_1} > 0$.

The effect of natural disasters becomes less obvious when they affect migration costs. The occurrence of a negative exogenous shock increases the demand for immigrating and raises the equilibrium prices for immigration services (Mahajan & Yang, 2020). For some individuals in foreign countries climate change-related extreme events reduce the ability to cover the fixed migration costs and raise the opportunity cost of departure (Mahajan & Yang, 2020). In this sense negative shocks which increase migration costs reduce migration to the United States ($i.e. \boldsymbol{\alpha_1} < 0$).

3.5. Results

In this paper I estimate the effect of climate change-related extreme events on migration from foreign territories to the United States. I empirically test the models outlined in Section 3.4 by using migration data from the Department of State and linking that with data from the International Disasters Database (EM-DAT). My focus is on four types of climate change-related events: storms, floods, droughts, and extreme temperature. Specifically, their monetary damage and the number of lives affected. In this paper, the monetary damage and lives affected by these extreme events can be understood as increasing the benefits of migrating to the US for foreign residents.

3.5.1. Main Results

Immigration to the United States can be a long process. Bier (2019) states the average immigration wait time to the United States increased from an average of 2 years in 1991 to an average of 5 years in 2018. Therefore, we would not expect climate change-related extreme events to have a contemporaneous effect on legal migration and I estimate the effects of two and three-year lags of these events on migration. The main results of this study are presented in Tables 3.3 to 3.6.

In Table 3.3 I present the results from estimating the effect of the monetary damage of climate change-related events with a two-year lag on migration inflow per 100,000 to the US[12]. In Panel A, we see that floods and droughts reduce levels of emigration to the US for the sample of

[12] I also estimate the effect of a two-period lag on climate change-related extreme events on migration inflows to the US using data from the American Community Survey that spans the years 2006 to 2017. The estimates suggest that the impact of floods and droughts on migration flows are not statistically different from zero. This is also the case for the cumulative monetary damage of the climate change-related extreme events.

all countries. In column (1) I excluded remittances (% GDP) and in column (2), I control for remittances (% GDP).

Table 3.3

The Effect of the Monetary Damage of Climate Change-Related Events on Migration Inflows (per 100,000) to the US (2-years lags)

VARIABLES	(1) migrants	(2) migrants	(3) migrants	(4) migrants	(5) migrants
Panel A: All Countries, 2 lags					
Storm damage (% GDP) 2 lags	-0.0872	0.112			
	(0.190)	(0.269)			
Flood damage (% GDP) 2 lags	-5.664**	-5.712**			
	(2.538)	(2.553)			
Drought damage (% GDP) 2 lags	-2.674*	-2.161*			
	(1.502)	(1.265)			
Extr. Temp. damage (% GDP) 2 lags	0.176	0.165			
	(0.307)	(0.295)			
Total damage (% GDP) 2 lags			-0.239	-1.969	-2.095
			(0.438)	(1.735)	(1.951)
Observations	2,430	2,204	3,276	2,432	2,204
R-squared	0.058	0.063	0.008	0.030	0.035
Number of countries	158	148	196	158	148
Panel B: Low- and Middle-Income Countries, 2 lags					
Storm damage (% GDP) 2 lags	0.0832	0.155			
	(0.263)	(0.298)			
Flood damage (% GDP) 2 lags	-5.741**	-5.777**			
	(2.513)	(2.526)			
Drought damage (% GDP) 2 lags	-1.686	-1.493			
	(1.359)	(1.240)			
Extr. Temp. damage (% GDP) 2 lags	0.204	0.203			
	(0.343)	(0.321)			
Total damage (% GDP) 2 lags			-0.252	-2.129	-2.139
			(0.455)	(1.984)	(2.037)
Observations	1,718	1,599	2,147	1,720	1,599
R-squared	0.072	0.076	0.016	0.044	0.047
Number of countries	121	116	140	121	116

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Notes: This table shows the effect of the monetary damage (% GDP) of climate change-related events on immigration inflows (per 100,000) to the US. Each column shows the results from fixed effects estimation with constant term, the control variables, country fixed effects, and year fixed effects. In column (1) the estimation excludes remittances (% GDP) but in column (2) remittances (% GDP) is included. In columns (3)-(5) the estimated is done with the main variable of interest being the cumulative monetary damage of the climate change-related events. Column (3) excludes all country variables, column (4) excludes remittances (% GDP) and column (5) includes remittances (% of GDP).

In both columns (1) and (2) in Panel A, we see that a one percent increase in flood damage (% GDP) cause emigration to decline by approximately 6 per 100,000 of home-country population. In Panel A, we see a similar direction of the effect of droughts on migration inflows. As seen in columns (1) and (2) a one percent increase in the monetary damage of droughts leads to a decline in migration inflows by 2 to 3 per 100,000 of home-country population. The effects of floods and droughts are substantial when compared to the sample average for all countries. The decline due to floods and droughts is approximately 19% and 8.7% of the sample mean for all countries respectively. In Panel B, we see a similar magnitude for an increase in the monetary damage of floods for low-and-middle income countries. The results show that a one percent increase in flood damage per GDP leads to a decline in immigrant inflows from low-and-middle income countries by 6 per 100,000. This again is considerable relative to the sample mean for low-and-middle income countries. This decline in migration flows to the US represents approximately 17% of the sample average. The effect of cumulative monetary damage on migration is not statistically different from zero. Rather, here, it is the individual extreme event which affects migration inflows to the US.

In Table 3.4, I present the results for the three-years lag of the monetary damage of climate change-related events on migration inflows to the US, for the sample of all countries and low-and-middle income countries respectively. In Panel A, a one percent increase in the monetary damage of storms and droughts leads to a reduction in migration inflows to the US by 1 per 100,000 of the home-country population. The effect is similar for low-and-middle income countries. In Panel B, the results show a one percent increase in the monetary damage of storms and droughts (% GDP) reduce migration to the US by 1 per 100,000. Compared to the migration inflow mean for both samples, the estimates for storms indicate that migration declines by 3.3% for the sample of all countries and 2.9% for the sample of low-and-middle income countries. On the other hand, Table 3.4 shows that an increase in the monetary damage of floods (% GDP) leads to an increase in migration inflows to the US. Specifically, a one percent increase in the monetary damage of floods increase migration by 0.57 per 100,000 of the home-country population. That is, a 10 percent increase in the flood damage (% GDP) leads to an increase in migration flows to the US by 5.7 per 100,000. Overall, the results in Table 3.4 again suggest that migration to the US is affected by the monetary damage of the type of climate change-related extreme events rather than the cumulative damage of all extreme events[13].

[13] A similar estimation was done using ACS migration data. However, the results indicate that except for the extreme temperature, there is no statistically significant effect of climate change-related extreme events on migration inflows to the US. It is important to note that for the ACS sample, the dependent variable is the unweighted measure of the number of migrants immigrating from a sample of foreign countries and thus may not give a precise estimate of the estimated migration inflows. Rather, what is of important in the sign of the sign of the coefficient. For the estimation of the three-years lag, this is consistent with my primary results.

Table 3.4

The Monetary Damage of Climate Change-Related Events on Migration Inflows per 100,000 to the US (3-years lags)

VARIABLES	(1) migrants	(2) migrants	(3) migrants	(4) migrants	(5) migrants
Panel A: All Countries [3 lags]					
Storm damage (% GDP) 3 lags	-1.052***	-1.121**			
	(0.375)	(0.484)			
Flood damage (% GDP) 3 lags	0.570**	0.529**			
	(0.220)	(0.214)			
Drought damage (% GDP) 3 lags	-1.267*	-1.289*			
	(0.661)	(0.670)			
Extr. Temp. damage (% GDP) 3 lags	-0.0120	-0.274			
	(0.0803)	(0.348)			
Total damage (% GDP) 3 lags			-0.205**	-0.429	-0.435
			(0.0890)	(0.352)	(0.357)
Observations	2,280	2,078	3,087	2,282	2,078
R-squared	0.023	0.029	0.010	0.020	0.026
Number of countries	158	148	196	158	148
Panel B: Low- and Middle-Income Countries [3 lags]					
Storm damage (% GDP) 3 lags	-1.172**	-1.119**			
	(0.544)	(0.543)			
Flood damage (% GDP) 3 lags	0.521**	0.494**			
	(0.235)	(0.230)			
Drought damage (% GDP) 3 lags	-1.582*	-1.376*			
	(0.905)	(0.801)			
Extr. Temp. damage (% GDP) 3 lags	-0.0448	-0.309			
	(0.0962)	(0.352)			
Total damage (% GDP) 3 lags			-0.214**	-0.437	-0.434
			(0.0963)	(0.366)	(0.347)
Observations	1,604	1,502	2,014	1,606	1,502
R-squared	0.041	0.044	0.021	0.037	0.041
Number of countries	118	113	136	118	113

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Notes: This table shows the effect of the monetary damage (% GDP) of climate change-related events on immigration inflows (per 100,000) to the US. Each column shows the results from fixed effects estimation with constant term, the control variables, country fixed effects, and year fixed effects. In column (1) the estimation excludes remittances (% GDP) but in column (2) remittances (% GDP) is included. In columns (3)-(5) the estimated is done with the main variable of interest being the cumulative monetary damage of the climate change-related events. Column (3) excludes all country variables, column (4) excludes remittances (% GDP) and column (5) includes remittances (% of GDP). The variable "migrants" is constructed using data from the Department of State – Bureau of Consular Affairs. The variables for climate change-related events are constructed using data from and the International Disaster Database and World Development Indicator Database.

In Tables 3.5 and 3.6 I present the two- and three-years lag results of estimating the effect of the number of lives affected by climate change-related events on migration to the US per 100,000 of the home-country population. Table 3.5 shows the effects of the two-years lag effect of the number of lives affected by climate change-related extreme events for all countries and low-and-middle income countries respectively. As shown in Panel A, the results indicate that the number of lives affected by storms and extreme temperature have a significant impact on emigration to the US. For storms, a 10 percent increase in the number of lives affected leads to a reduction in the emigration to the US by 2 per 100,000 of the home-country population. For extreme temperature, we observe in column (2) that a 10 percent increase in the number of lives affected leads to an increase in emigration to the US by 0.4 per 100,000 of home-country population. The estimates for storms can be interpreted as having relative economic significance since the estimated decline in migration flows to the US is equivalent to 6.7% of the average for the sample of all countries and 5.7% for the sample of low-and-middle income countries.

Table 3.5

The Effect of the Number of Lives Affected by Climate Change-Related Extreme Events on Migration per 100,000 to the US (2-years lags).

VARIABLES	(1) migrants	(2) migrants	(3) migrants	(4) migrants	(5) migrants
Panel A: All Countries [2 lags]					
Storm affected (% pop) 2 lags	-0.228***	-0.216*			
	(0.0767)	(0.111)			
Flood affected (% pop.) 2 lags	-1.742	-1.749			
	(1.358)	(1.354)			
Drought affected (% pop.) 2 lags	-0.0147	-0.0107			
	(0.0461)	(0.0707)			
Extr. Temp. affected (% pop.) 2 lags	0.0336	0.0416*			
	(0.0232)	(0.0216)			
Total affected (% pop.) 2 lags			-0.149	-0.292	-0.326
			(0.158)	(0.246)	(0.290)
Observations	2,432	2,204	3,276	2,432	2,204
R-squared	0.043	0.048	0.008	0.020	0.025
Number of countries	158	148	196	158	148
Panel B: Low- and Middle-Income Countries					
Storm affected (% pop) 2 lags	-0.215**	-0.217			
	(0.0950)	(0.137)			
Flood affected (% pop.) 2 lags	-1.780	-1.786			
	(1.385)	(1.379)			
Drought affected (% pop.) 2 lags	0.00723	0.00785			
	(0.0492)	(0.0755)			
Extr. Temp. affected (% pop.) 2 lags	0.0328	0.0418**			
	(0.0208)	(0.0208)			
Total affected (% pop.) 2 lags			-0.161	-0.282	-0.322
			(0.183)	(0.252)	(0.298)
Observations	1,720	1,599	2,147	1,720	1,599
R-squared	0.058	0.060	0.016	0.033	0.036
Number of countries	121	116	140	121	116

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Notes: This table shows the effect of the number of lives affected (human impact) as a one percent of the home-country population by climate change-related events on immigration inflows (per 100,000) to the US. Each column shows the results from fixed effects estimation with constant term, the control variables, country fixed effects, and year fixed effects. In column (1) the estimation excludes remittances (% GDP) but in column (2) remittances (% GDP) is included. In columns (3)-(5) the estimated is done with the main variable of interest being the cumulative number of lives affected by the climate change-related events. Column (3) excludes all country variables, column (4) excludes remittances (% GDP) and column (5) includes remittances (% of GDP). The variable "migrants" is constructed using data from the Department of State – Bureau of Consular Affairs. The variables for climate change-related events are constructed using data from and the International Disaster Database and World Development Indicator Database.

However, the estimated effect of a 10% increase in the population affected by extreme temperature represents 1.3% of the sample mean for all countries and 1.1% for the sample of low-and-middle income countries. These climate change-related extreme events have similar impact on low-and-middle income countries, as presented in Panel B. In sum, Table 3.5 indicate that only the category of the climate change events has a statistically significant effect on migration flows to the US rather than the cumulative impact.

Table 3.6 presents the results for estimating the three-years lag effect of the number of lives affected by climate change-related extreme events on migration flows to the US. In Panel A, the results show that a 10% increase in the number of lives affected by storms leads to a decline in migration inflow to the US by 2.4 per 100,000 of the home-country population. This effect is like the estimates for the sample of low-and-middle income countries. In addition, a 10% increase in the number of lives affected by extreme temperature leads to an increase in migration inflows to the US by 1.5 per 100,000 of the home-country population. Finally, we observe that the cumulative number of lives affected by climate change extreme events does not have a significant impact on migration inflows to the US[14].

[14] A similar analysis using the ACS migration data was conducted for the two and three period lags of the number of lives affected. The results indicate that, except for extreme temperature, the effect of climate change-related extreme events is not statistically different from zero. For extreme temperature, it has a negative impact on the number of migrants to the US.

Table 3.6

The Number of Lives Affected by Climate Change-Related Extreme Events on Migration per 100,000 to the US (3-years lags).

VARIABLES	(1) migrants	(2) migrants	(3) migrants	(4) migrants	(5) migrants
Panel A: All Countries [3 lags]					
Storm affected (% pop.) 3 lags	-0.238**	-0.252*			
	(0.110)	(0.145)			
Flood affected (% pop.) 3 lags	0.193	0.186			
	(0.174)	(0.162)			
Drought affected (% pop.) 3 lags	-0.0501	-0.0385			
	(0.0389)	(0.0726)			
Extr. Temp. affected (% pop.) 3 lags	0.155***	0.150***			
	(0.0289)	(0.0388)			
Total affected (% pop.) 3 lags			-0.0753**	-0.0232	-0.00534
			(0.0376)	(0.0528)	(0.0654)
Observations	2,282	2,078	3,087	2,282	2,078
R-squared	0.021	0.027	0.009	0.019	0.025
Number of countries	158	148	196	158	148
Panel B: Low- and Middle-Income Countries					
Storm affected (% pop.) 3 lags	-0.213*	-0.235			
	(0.118)	(0.156)			
Flood affected (% pop.) 3 lags	0.209	0.201			
	(0.173)	(0.162)			
Drought affected (% pop.) 3 lags	-0.0543	-0.0395			
	(0.0416)	(0.0757)			
Extr. Temp. affected (% pop.) 3 lags	0.154***	0.147***			
	(0.0296)	(0.0405)			
Total affected (% pop.) 3 lags			-0.0776**	-0.0160	0.00202
			(0.0386)	(0.0503)	(0.0641)
Observations	1,606	1,502	2,014	1,606	1,502
R-squared	0.038	0.042	0.020	0.036	0.040
Number of countries	118	113	136	118	113

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Notes: This table shows the effect of the number of lives affected (human impact) as a one percent of the home-country population by climate change-related events on immigration inflows (per 100,000) to the US. Each column shows the results from fixed effects estimation with constant term, the control variables, country fixed effects, and year fixed effects. In column (1) the estimation excludes remittances (% GDP) but in column (2) remittances (% GDP) is included. In columns (3)-(5) the estimated is done with the main variable of interest being the cumulative number of lives affected by the climate change-related events. Column (3) excludes all country variables, column (4) excludes remittances (% GDP) and column (5) includes remittances (% of GDP). The variable "migrants" is constructed using data from the Department of State – Bureau of Consular Affairs. The variables for climate change-related events are constructed using data from and the International Disaster Database and World Development Indicator Database.

3.5.2. Alternative Results

I also present additional results of the effects of climate change-related extreme events on migration per 100,000 of home-country population. These results consider lower and higher order of lags, the frequency of the extreme events, and the duration. In Table 3.7, I present the contemporaneous effects of the extreme events on migration inflows to the US. The results show in Panel A, a one percent increase in the monetary damage of floods increase migration inflows to the US by approximately 6 per 100,000 of the home-country population. This result is similar when looking at low-and-middle income countries. A one percent increase in the monetary damage of floods increase migration inflows from low-and-middle income countries by 6 per 100,000. There is no evidence to suggest that the cumulative monetary damage of the climate change-related extreme events leads to change in migration patterns to the US; rather migration flow is affected by the type of extreme event.

Table 3.7
The Monetary Damage of Climate Change-Related Extreme Events on Migration per 100,000 to the US (no lags).

VARIABLES	(1) migrants	(2) migrants	(3) migrants	(4) migrants	(5) migrants
Panel A: All Countries [no lags]					
Storm damage (% GDP)	0.880	0.949			
	(0.767)	(0.939)			
Flood damage (% GDP)	6.210**	6.219**			
	(2.539)	(2.551)			
Drought damage (% GDP)	-0.860	-0.864			
	(0.787)	(0.879)			
Extr. Temp. damage (% GDP)	-0.120	0.0272			
	(0.263)	(0.364)			
Total damage (% GDP)			-0.348**	2.497	2.743
			(0.174)	(1.587)	(1.739)
Observations	2,728	2,450	3,652	2,728	2,450
R-squared	0.059	0.063	0.017	0.035	0.041
Number of countries	158	149	196	158	149
Panel B: Low- and Middle-Income Countries [no lags]					
Storm damage (% GDP)	1.091	1.090			
	(0.912)	(0.956)			
Flood damage (% GDP)	6.266**	6.285**			
	(2.567)	(2.577)			
Drought damage (% GDP)	-0.914	-0.870			
	(0.802)	(0.923)			
Extr. Temp. damage (% GDP)	-0.0651	0.111			
	(0.234)	(0.344)			
Total damage (% GDP)			-0.353*	2.836	2.890
			(0.181)	(1.760)	(1.788)
Observations	1,944	1,787	2,407	1,944	1,787
R-squared	0.074	0.076	0.024	0.051	0.053
Number of countries	121	117	140	121	117

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Notes: This table shows the effect of the monetary damage (% GDP) of climate change-related events on immigration inflows (per 100,000) to the US. Each column shows the results from fixed effects estimation with constant term, the control variables, country fixed effects, and year fixed effects. In column (1) the estimation excludes remittances (% GDP) but in column (2) remittances (% GDP) is included. In columns (3)-(5) the estimated is done with the main variable of interest being the cumulative monetary damage of the climate change-related events. Column (3) excludes all country variables, column (4) excludes remittances (% GDP) and column (5) includes remittances (% of GDP). The variable "migrants" is constructed using data from the Department of State – Bureau of Consular Affairs. The variables for climate change-related events are constructed using data from and the International Disaster Database and World Development Indicator Database

Table 3.8

The Number of Lives Affected by Climate Change-Related Extreme Events on Migration Inflows per 100,000 to the US (no lags).

VARIABLES	(1) migrants	(2) migrants	(3) migrants	(4) migrants	(5) migrants
Panel A: All Countries [no lags]					
Storm affected (% pop.)	0.135	-0.0220			
	(0.145)	(0.230)			
Flood affected (% pop.)	1.587*	1.597*			
	(0.824)	(0.827)			
Drought affected (% pop.)	-0.0335	-0.0536			
	(0.0311)	(0.0500)			
Extr. Temp. affected (% pop.)	-0.0508	-0.0447			
	(0.0395)	(0.0477)			
Total affected (% pop.)			-0.0620	0.170	0.205
			(0.176)	(0.125)	(0.181)
Observations	2,728	2,450	3,652	2,728	2,450
R-squared	0.035	0.040	0.007	0.015	0.020
Number of countries	158	149	196	158	149
Panel B: Low- and Middle-Income Countries [no lags]					
Storm affected (% pop.)	0.146	-0.00243			
	(0.150)	(0.256)			
Flood affected (% pop.)	1.615*	1.624*			
	(0.823)	(0.826)			
Drought affected (% pop.)	-0.0603*	-0.0739			
	(0.0357)	(0.0541)			
Extr. Temp. affected (% pop.)	-0.0461	-0.0406			
	(0.0461)	(0.0531)			
Total affected (% pop.)			-0.0730	0.162	0.203
			(0.197)	(0.127)	(0.185)
Observations	1,944	1,787	2,407	1,944	1,787
R-squared	0.049	0.051	0.013	0.028	0.029
Number of countries	121	117	140	121	117

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Notes: This table shows the effect of the number of lives affected (human impact) as a one percent of the home-country population by climate change-related events on immigration inflows (per 100,000) to the US. Each column shows the results from fixed effects estimation with constant term, the control variables, country fixed effects, and year fixed effects. In column (1) the estimation excludes remittances (% GDP) but in column (2) remittances (% GDP) is included. In columns (3)-(5) the estimated is done with the main variable of interest being the cumulative number of lives affected by the climate change-related events. Column (3) excludes all country variables, column (4) excludes remittances (% GDP) and column (5) includes remittances (% of GDP). The variable "migrants" is constructed using data from the Department of State – Bureau of Consular Affairs. The variables for climate change-related events are constructed using data from and the International Disaster Database and World Development Indicator Database.

Table 3.8 shows the effect of the number of lives affected by climate change-related extreme events on migration flows to the US. The results indicate that a one percent increase in the monetary damage of flood induce migration flow to the US by 1.6 per 100,000 of home-country population. In Columns (3) to (5) we observe that there is no evidence the total number of lives affected by extreme events affect migration flows per 100,000 to the US.

In Table 3.9, I consider the effect of a higher lag order. The results shown indicate the four-years lag of the monetary damage of climate change-related extreme events on migration flow to the US. In Panel A, for the sample of all countries, the estimates indicate that a 10 percent increase in storm monetary damage and flood damage leads to a decline in migration flows to the US by 8.3 per 100,000 and 9.2 per 100,000 of home-country population, respectively. There is a similar effect with slightly higher magnitude for low-and-middle income countries. In Panel B the results for low-and-middle income countries show that a 10 percent increase in storm monetary damage and flood damage leads to a decline in migration flow to the US by 8.3 per 100,000 and 9.6 per 100,000 respectively. In addition, Table 3.9 shows the 4-years lag of the cumulative monetary damage has negative and statistically significant effect on migration flows to the US. A 10 percent increase in the cumulative monetary damage of the extreme events leads to a decline in migration inflows of approximately 8 per 100,000 of the home-country population.

Table 3.9

The Monetary Damage of Climate Change-Related Extreme Events on Migration Flows per 100,000 to the US (4 lags).

VARIABLES	(1) migrants	(2) migrants	(3) migrants	(4) migrants	(5) migrants
Panel A: All Countries [4 lags]					
Storm damage (% GDP) [4 lags]	-0.798***	-0.839***			
	(0.213)	(0.249)			
Flood damage (% GDP) [4 lags]	-0.901*	-0.921*			
	(0.511)	(0.502)			
Drought damage (% GDP) [4 lags]	-1.022	-0.663			
	(0.908)	(0.651)			
Extr. Temp. damage (% GDP) [4 lags]	0.0326	-0.224			
	(0.0670)	(0.313)			
Total damage (% GDP) [4 lags]			-0.171	-0.761***	-0.805***
			(0.169)	(0.273)	(0.297)
Observations	2,129	1,949	2,898	2,132	1,949
R-squared	0.023	0.028	0.010	0.022	0.028
Number of countries	158	148	196	158	148
Panel B: Low- and Middle-Income Countries [4 lags]					
Storm damage (% GDP) [4 lags]	-0.885***	-0.834***			
	(0.299)	(0.294)			
Flood damage (% GDP) [4 lags]	-0.955*	-0.959*			
	(0.500)	(0.493)			
Drought damage (% GDP) [4 lags]	-0.789	-0.469			
	(0.990)	(0.736)			
Extr. Temp. damage (% GDP) [4 lags]	0.00569	-0.260			
	(0.0839)	(0.321)			
Total damage (% GDP) [4 lags]			-0.171	-0.818***	-0.815**
			(0.173)	(0.310)	(0.323)
Observations	1,492	1,405	1,885	1,495	1,405
R-squared	0.039	0.043	0.019	0.039	0.043
Number of countries	116	111	134	116	111

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Notes: This table shows the effect of the monetary damage (% GDP) of climate change-related events on immigration inflows (per 100,000) to the US. Each column shows the results from fixed effects estimation with constant term, the control variables, country fixed effects, and year fixed effects. In column (1) the estimation excludes remittances (% GDP) but in column (2) remittances (% GDP) is included. In columns (3)-(5) the estimated is done with the main variable of interest being the cumulative monetary damage of the climate change-related events. Column (3) excludes all country variables, column (4) excludes remittances (% GDP) and column (5) includes remittances (% of GDP). The variable "migrants" is constructed using data from the Department of State – Bureau of Consular Affairs. The variables for climate change-related events are constructed using data from and the International Disaster Database and World Development Indicator Database.

For the number of lives affected by climate change-related extreme events, the results for four-years lag are shown in Table 3.10. In Panel A, the results indicate that the effect of storms, floods, droughts, and extreme temperature on migration are not statistically different from zero. This is also the case for Panel B which shows the estimates on migration to the US from low-and-middle income countries. Further, once control variables are included, there is no effect of the cumulative number of lives affected on migration to the US. Overall the results of the 4-period lag show that monetary damage leads to changes in migration to the US but there is no evidence the number of lives affected leads to such pattern.

Table 3.10

The Number of Lives Affected by Climate Change-Related Events on Migration per 100,000 to the US (4 lags).

VARIABLES	(1) migrants	(2) migrants	(3) migrants	(4) migrants	(5) migrants
Panel A: All Countries [4 lags]					
Storm affected (% pop.) [4 lags]	-0.143	-0.0973			
	(0.0973)	(0.108)			
Flood affected (% pop.) [4 lags]	-0.376	-0.372			
	(0.379)	(0.385)			
Drought affected (% pop.) [4 lags]	-0.0497	-0.0290			
	(0.0321)	(0.0529)			
Extr. Temp. affected (% pop.) [4 lags]	-0.0103	-0.00903			
	(0.0144)	(0.0183)			
Total affected (% pop.) [4 lags]			-0.117**	-0.104	-0.0883
			(0.0519)	(0.0683)	(0.0728)
Observations	2,132	1,949	2,898	2,132	1,949
R-squared	0.021	0.026	0.010	0.020	0.025
Number of countries	158	148	196	158	148
Panel B: Low- and Middle-Income Countries [4 lags]					
Storm affected (% pop.) [4 lags]	-0.111	-0.0591			
	(0.106)	(0.119)			
Flood affected (% pop.) [4 lags]	-0.369	-0.364			
	(0.402)	(0.407)			
Drought affected (% pop.) [4 lags]	-0.0595	-0.0382			
	(0.0362)	(0.0572)			
Extr. Temp. affected (% pop.) [4 lags]	-0.0208	-0.0213			
	(0.0240)	(0.0262)			
Total affected (% pop.) [4 lags]			-0.107*	-0.102	-0.0854
			(0.0567)	(0.0709)	(0.0764)
Observations	1,495	1,405	1,885	1,495	1,405
R-squared	0.037	0.041	0.020	0.036	0.040
Number of countries	116	111	134	116	111

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Notes: This table shows the effect of the number of lives affected (human impact) as a one percent of the home-country population by climate change-related events on immigration inflows (per 100,000) to the US. Each column shows the results from fixed effects estimation with constant term, the control variables, country fixed effects, and year fixed effects. In column (1) the estimation excludes remittances (% GDP) but in column (2) remittances (% GDP) is included. In columns (3)-(5) the estimated is done with the main variable of interest being the cumulative number of lives affected by the climate change-related events. Column (3) excludes all country variables, column (4) excludes remittances (% GDP) and column (5) includes remittances (% of GDP). The variable "migrants" is constructed using data from the Department of State – Bureau of Consular Affairs. The variables for climate change-related events are constructed using data from and the International Disaster Database and World Development Indicator Database.

In addition to lower and higher lag orders, in Table 3.11 I summarize the direction and level of significance for the effect of the duration and frequency of the climate change-related extreme events.

Table 3.11
Comparison of the Effects from the Frequency and Duration of Climate Change-Related Extreme Events on Migration per 100,000 to the US by Samples of all Countries and Low- and Middle-Income Countries.

	ALL COUNTRIES				LOW- AND MIDDLE-INCOME COUNTRIES			
	Storms	Flood	Drought	Extr. Temp	Storms	Flood	Drought	Extr. Temp
US Department of State - Bureau of Consular Affairs								
Frequency [no lag]	(0)	(0)	(-)	(0)	(0)	(0)	(0)	(0)
Frequency [2 lags]	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Frequency [3 lags]	(0)	(0)	(0)	(0)	(0)	(-)	(0)	(0)
Duration [no lag]	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(+)
Duration [2 lags]	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Duration [3 lags]	(0)	(0)	(0)	(-)	(0)	(0)	(0)	(-)

Notes: The table summarizes the effects of the frequency and duration of climate change-related extreme events on migration per 100,000 of home-country population to the US. Each column refers to fixed effects estimation with all control variables, a constant term, country of origin fixed effects, and year fixed effects. In this table, (0) indicates no statistically significant effect while (+) or (-) indicate the sign of the statistically significant variable.

The effect of the frequency of the climate change-related events are not statistically different from zero. The effects for duration resemble this effect of frequency overall. We do observe that the contemporaneous effect of extreme temperature duration leads to a positive and significant effect on migration flows to the US. By contrast, the three-years lag of duration have a negative and significant effect on migration flows to the US.

3.6. Conclusion

I examine the impact of climate change-related extreme events on legal international migration to the United States. Using data on four types of extreme events associated with climate change, I test whether storms, floods, droughts, and extreme temperature led to changes in migration inflows to the US. Because of the slow immigration process, the contemporaneous impact of climate change-related extreme events on migration may give us a limited view of the effects climate change-related events have on migration inflows to the US (Mahajan & Yang, 2020). In particular, because of well-known backlogs in the immigration process, which Bier (2019) finds to be around 3 years, my estimations are the those following 2-years and 3-years lags.

I find that when we consider the monetary damage and the human impact of climate change-related extreme events, there is distinction in the category of extreme events that cause a change in migration patterns. Except for the three-years lag specification, flood and drought monetary damage are the main sources of changes in migration inflow to the US. This is in contrast with how migration pattern responds to the number of lives affected. I find that only the human impact from storms and extreme temperature have statistically significant impact on migration to the US.

The sign of the effect on migration from monetary damage and the number of lives affected are consistent and, in some cases, economically significant. For monetary damage, the results from the two-years lag are negative for flood and droughts. This estimated decline in migration flows to the US from a 1 percent increase in floods and droughts monetary damage amounts to 20% and 6.7% of the sample average for migration flows. For low-and-middle income countries, only flood is statistically and economically significant; with an estimated decline in migration flows being approximately 17.1% of the sample average.

For the number of lives affected, the impact on migration flows is different. When considering the number of lives affected, the signs of the storms and extreme temperature are negative and positive respectively. For the two-years and three-years lag effect only storms and extreme temperature have an impact that is statistically different from zero. In term of economic significance, the two- and three-years lags estimations are however marginal. Specifically, the effects amount to at most 0.7% of the sample mean.

The results from monetary damage and the number of lives affected indicate that the cumulative measures of climate change-related extreme events, although consistently negative, are not statistically different from zero. This finding suggest that migration is more sensitive to a type of extreme event rather than the total monetary damage or the total number of lives affected.

Overall, except for two cases, this study suggests that the impact of climate change-related events is either null or negative. The first case we observe a positive effect is for the three-years lag for floods monetary damage and the second case three-years lag for extreme temperature human impact. The main results from this study suggest that climate change-related extreme events do affect migration costs. It highlights that these extreme events raise the pecuniary cost of migration or causes a change in foreign residents' choice to migrate. That is, these results indicate that climate change-related extreme events reduce the ability of people to migrate because of worsen liquidity constraints. A first consequence of this is possibly a development trap where individuals who are not able migrate to countries like the US and receive relatively higher income gains will be more vulnerable to poverty. Another possible outcome of these results is immigration policy. People impacted by climate change-related extreme events may migrate where they can and not necessarily where they should or desire. The policy implication of this study, specifically for migrant sending-countries is that reduce out-migration after such exogenous shock may be indicative of people's need to resource to overcome the burdens placed on them due to these extreme events. Finally, a policy implication of this study is the call for all countries to create a contingency plan for the people who are most "climate change-vulnerable" to not fall into poverty.

Some limitations of this study relate to legal migration, waiting time to migrate to the US, and financial development. First, the main results capture a limited amount of the legal migration flow to the US and therefore may underestimate the effects of climate change-related events on migration. Second, it does not include the average wait times; another aspect of the immigration process that may be important for further research. A third limitation of this study is that financial development could play a role in migration decisions. Specifically, while GDP per capita gives an estimate of the well-being of foreign countries, it does not capture specific information about credit to households and businesses that would help buffer climate change-related extreme events. Finally, migration flow to the US after climate change-related event may have regional differences. Future research considering migration flow to the US due to these extreme events would benefit from considering regional differences.

This study contributes to our understanding of the effect of migration due to climate change-related events. These findings are applicable to immigration and climate change policy implementation in both the migrant-origin country and the migrant-receiving countries. Severe natural disasters can lead to the loss of human and capital resources which may be difficult to recoup. This could hinder the growth and development of the migrant-origin country. Understanding the consequences of natural disasters for these countries should inform climate policymakers to implement more robust and strategic plans. Policymakers in destination countries can also benefit from understanding another determinant of immigration or source for brain-drain.

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CHAPTER 4

LABOR MARKET OUTCOMES OF RECENT PUERTO RICAN MIGRANTS IN MAINLAND POST-MARIA

4.1. Introduction

In this paper I examined, using the synthetic control method, the labor market outcomes of recent Puerto Rican migrants who moved to Florida and New York, post - Hurricane Maria. In this paper and using the American Community Survey's (ACS) definition, a "recent Puerto Rican migrant" is defined as a person who lived in Puerto Rico in the previous year and currently lives on the mainland. For labor market outcomes, the unemployment rate for recent Puerto Rican migrants is defined as Puerto Ricans who internally migrated to the mainland and who are without a job, seeking one but are unable to find one. I also examined the effect of this move to the mainland on the labor force participation rate for this specific group of American citizens. Unlike the technique used in previous studies examining the effect of immigration on aggregate-level labor market outcomes, I employ the synthetic control method (SCM). The synthetic control method was introduced by Abadie & Gardeazabal (2003) and further developed by Abadie et al. (2010) to study the evolution of aggregate outcomes.

There are many papers in the labor-immigration literature regarding the effect of immigration on wages, employment, and other local and aggregate labor market outcomes. Like Card (1990), Mcintosh (2008), and Silva et al. (2010), studies have focused their analysis on local and state labor market impacts. In addition, a number of studies that examined labor market outcomes utilize either the double difference and/or triple difference technique. A number of these studies were particularly interested in the two major hurricanes prior to Maria: Hurricane Katrina and Hurricane Mitch. Although these previous studies provide insight into the changes in wages and employment for certain skill level of workers (Kugler & Yuksel, 2008); demand for local goods and services (Silva et al., 2010); and direct and neighboring effects (Belasen & Polachek, 2008), they have several shortcomings.

In this paper I make two contributions that address the shortcomings of the labor-immigration literature. My first contribution is the focus on the labor market impact of Hurricane Maria on Puerto Ricans moving to the US. Hinojosa et al. (2018) report that Hurricane Maria was the third most devastating hurricane in U.S. history. Making landfall in Puerto Rico on September 20, 2017, Hinojosa et al. (2018) show that Hurricane Maria landfall caused expansive damages to infrastructure and residents' lives summing billions of dollars of losses for the country. Another consequence of Hurricane Maria according to Hinojosa et al. (2018) was the migration of thousands of residents to the mainland. This sudden and exogenous shock provides the unique opportunity to study the labor market outcomes of those who likely had to move unexpectedly compared to those who were able to plan their move to the mainland.

The second contribution I make to address a shortcoming of the labor-immigration literature is taking advantage of the synthetic control method. This method offers an opportunity to improve our evaluation of exogenous events and perform quasi-experimental analysis in ways not given by traditional regression based methods; much to the likes of Peri & Yasenov's (2019) re-examination of the Mariel Boatlift labor market effects which was previously studied by Card (1990) and Borjas (2017).

This paper evaluates the labor market effect of Puerto Rican migration to the US that is due to a climate change-related event[15]. The use of the synthetic control method overcomes a

[15] Although I use the term "migrant" in this paper for convenience, I recognize that Puerto Ricans are US citizens and thus internal migrants.

prevailing issue in many case studies (Abadie & Gardeazabal, 2003). This method relies on a data-driven procedure that requires researchers to establish quantifiable similarities between units that are affected and units unaffected. Further a feature of the synthetic control method is its unrestricted access to post-intervention outcomes. The feature allows researchers to choose the study design without knowing whether they will affect the conclusion.

The results of the analysis show that despite a large influx of recent Puerto Ricans to Florida and New York after Hurricane Maria, those arriving after the hurricane did not have worse labor market outcomes than earlier recent Puerto Ricans.

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4.2. Literature Review

Hurricane Maria hit Puerto Rico on September 20, 2017. At the time of landfall, the Hurricane's maximum wind speed was just below the category 5 classification at 155 miles per hour. According to Pasch et al. (2017) and Hinojosa et al. (2018), Hurricane Maria was the third costliest hurricane in U.S. history after Hurricanes Harvey and Katrina. As revealed by Pasch et al. (2017) estimates of the damage range between $60 billion and $115 billion for Puerto Rico and U.S. Virgin Islands. The non-pecuniary damages of Hurricane Maria according to Pasch et al. (2017) is the direct death of 65 individuals and indirect death of hundred others. In 2018, Hinojosa et al. (2018) estimates that Hurricane Maria's death toll was 2,975.

Additionally, Hurricane Maria caused extensive damage to Puerto Rico's infrastructure. According to Pasch et al. (2017), Hurricane Maria damaged 80% of utility poles and led to the loss of power for almost all residents. Hinojosa et al. (2018) stated Hurricane Maria triggered such an extensive medical and housing operation, it was one of the largest in US history. Hinojosa et al. (2018) explain that in the aftermath of Hurricane Maria, Puerto Rico continued to deal with fragile electric grid, poor infrastructure, financial issues, and an increase in migration to the US mainland. Hinojosa et al. (2018) indicated more than 160,000 or 5% of residents left Puerto Rico for the mainland after Hurricane Maria. The increase in migration has led to school closures, the unprecedented occurrence of death rates exceeding birth rates, and deteriorating economic activities.

As exemplified by the actions of Puerto Ricans above, one strategy chosen by residents of a country in the event of a hurricane is migration (Mcintosh, 2008; Vigdor, 2008). Hurricane Maria was not the only event to disrupt economic activities for Puerto Ricans. Mora et al. (2017a) examined the impact of Puerto Rico's 2006 economic crisis on the emigration flow of Puerto

Ricans to the mainland. Using a differences-in-differences technique, Mora et al. (2017b) found the skill level of migrants to the US in recent times has been volatile when observable and unobservable factors are considered.

The economic research on hurricanes has long remained interested in how economic growth changes when economies experience such negative economic shocks. With well-known evidence that the average occurrence and intensity of storms will increase due to global warming it is imperative to understand what this means for labor markets in both the sending and receiving markets.

Nordhaus (2010) examined the economic impact of hurricanes that have made landfall in the US. Using ordinary least squares (OLS), Two Squares Least Squares (TSLS), and quantile regression, Nordhaus (2010) estimated the effect of wind speed on economic damage per GDP. He finds that the occurrences of hurricanes may continue to result in billions of dollars, greenhouse warming is expected to cause hurricane intensity to increase, and coastal areas such as New Orleans face the most serious of risks and would require greater climate resilience infrastructure and investments. Similarly, using cross-country data, Strobl (2012) examined the effect of hurricanes on the economic growth for countries in the Latin American and Caribbean (LAC) region. Utilizing a destruction index that is based on wind field model, Strobl (2012) estimated that the average hurricane strike will lead to a 0.84 percentage points decrease in economic growth for LAC countries. Extending this to the fiscal implications, Ouattara & Strobl (2013) through a vector autoregressive model (VAR) found hurricanes affecting the (LAC) region have short term effects on fiscal policy. For example, they found that government spending will rise and continue for up to 2 years as a result of hurricanes impact. However, the countries' public investment, debt and tax revenues are not affected by hurricanes. Since spending increases after a hurricane but revenue does not, Ouattara & Strobl (2013) concluded that over the short-term the strategic response of government is to engage in short-term debt financing.

Studies have also been interested not just in the aggregate output of economies and how they are affected by hurricanes but the underlying indicators of economic growth and development such as poverty, health, labor market outcomes, and migration. In 1998, Hurricane Mitch hit Central America with Honduras being the worst affected area. The significant damage to the country led to studies about how poor households were particularly affected and whether aid has or can play a crucial role to mitigate such problems. In their study, Morris et al. (2002) used the Alternating Logistic Regression method to assess how Hurricane Mitch has affected underdeveloped communities that does not have the proper pecuniary and non-pecuniary resources to buffer against such strong event. The study found that Hurricane Mitch caused significant harm to the poor in areas directly and indirectly affected. Although aid was given to the areas affected this was limited relative to the damage incurred. Furthering the work of Morris et al. (2002), Morris & Wodon (2003) assessed the effectiveness of aid provided to mitigate the consequences of Hurricane Mitch. Morris & Wodon (2003) using the Heckman model found that households with limited assets and those who incurred asset losses faced a greater probability of recurring aid. However, the amount of aid received was not related to those indicators. This suggests that it is possible to find those who need aid, but it is difficult to determine what level of aid to provide to households.

While aid is one crucial source to improve households' well-being and buffer against going into poverty, another element of well-being is happiness. Berlemann (2016) used an ordered logit model to investigate how hurricane risks impact the happiness and life satisfaction of households. The study highlights that individuals in poor and underdeveloped countries experienced less happiness and life satisfaction due to hurricanes while only life satisfaction is affected for groups in highly developed countries.

Other areas of the literature have studied the labor market effects of hurricanes. There are a number of studies that have looked at the effect of Hurricane Katrina, one of the most destructive hurricanes to date. Groen & Polivka (2008) estimated the effect of Hurricane Katrina on the labor market for New Orleans and the Gulf Coast of Alabama, Mississippi, and Louisiana. Using a differences-in-difference method, Groen & Polivka (2008) found that among evacuees a 10-percentage points increase in severe housing damage is associated with labor force participation falling by 0.8 percentage point, employment per capita falling by 3.4 percentage points, and unemployment increasing by 5.2 percentage points. The study also highlights a disparity in the labor market outcomes for returnees and non-returnees. Specifically, individuals who chose not to return to their pre-Katrina area faced harsher conditions. A 10-percentage point increase in housing damage led to an increase in unemployment rate of 4.7 percentage point for non-returnees compared to 1.5 percentage points for returnees.

A hurricane may lead to serious disruption to social and economic affairs. Mcintosh (2008) estimated whether Hurricane Katrina migrants to the Houston metro area impacted the local labor market outcomes. Mcintosh (2008) difference-in-differences analysis showed that migration due to Katrina is associated with wages declining by 1.8 percent and 0.5 percent decrease in the probability of being employed. Overall Mcintosh (2008) concluded that migrants to the Houston metro area mildly affected labor market outcomes in Houston. Hurricane Katrina not only resulted in the displacement of households but has also affected whether the desire for evacuees to return. Fussell et al. (2010) studied the return of displaced New Orleans residents over 14 months. The study shows that when considering socio-economic and demographic characteristics, black peoples' return to New Orleans is slower than white residents. However, the pace of return is insignificant when controlling for housing damage.

In addition to labor market outcomes, Vigdor (2008) examined the economic aftermath of Hurricane Katrina on New Orleans population and housing market. Two years after Hurricane Katrina, employment for all major sectors, except natural resources and mining and construction, declined; with the largest decline in state and local government employment. Average weekly wages, however, increased over that period for sectors excluding information, utilities, arts, and entertainment and recreation. Vigdor (2008) found that wages increase most rapidly in sectors linked to demolition, construction, and housing markets. Hurricane Katrina effectively led to the destruction of approximately two-thirds of the New Orleans' housing stock (Vigdor, 2008). Because this reduction in the supply of housing was more than the reduction in demand, Vigdor (2008) predicted the long-run housing prices in New Orleans is unlikely to return to pre-Katrina levels. For the population, the aftermath of Hurricane Katrina resulted in significant changes in population size and composition. Orleans Parish, St. Bernard Parish, and Plaquemines Parish experienced population declines of 50%, 75%, and 25% respectively. The population composition of individuals who identify as black declined from 68% to 59% while the Hispanic group increased from 3% to 4% after Hurricane Katrina.

Silva et al. (2010) estimated the effect of immigration to the Houston metro area on workers' earnings due to Hurricane Katrina. They analyze the effect of immigration on wages by evaluating average sales per firm, taking into consideration the demand of local goods and services which was lacking in previous research. Using a triple difference method, they found that Hurricane Katrina-induced migration decrease the average wages in Houston by 0.7 percent. This contrasts Kugler & Yuksel (2008) study which found that immigration of less-skilled workers positively impact the earnings of skilled natives but does not affect employment. Their results also indicate that recent immigration of Latin American had no wage effect on earlier Latin Americans. However, when controlling for other ethnic groups, the impact on employment is negative.

Belasen & Polachek (2013) estimated using a generalized differences-in-difference technique the impact of hurricanes on wage and employment of local labor markets in Florida. The study finds that hurricanes led to a decrease in employment of at most 4.76% and a rise in earnings of 4.35% when the area is directly affected. However, neighboring countries experienced a decrease in earnings of about 4.5%. These effects however vary based on the intensity and the industry effect. Belasen & Polachek (2013) showed the direct effect of categories 4-5 hurricanes reduce employment by 4.76% but increase earnings by 4.35%. This is in contrast to a rise in employment of 1.47% and earnings of 1.28% for categories 1-3 hurricanes making direct hit. However, the results show that hurricanes do not have any significant effect on neighboring regions employment, but it does reduce wages by 4.51% and 33.33% for categories 1-3 and categories 4-5 hurricanes respectively. For sectoral employment the results indicate that employment in trade, transportation, and utility decrease by 6.79% but services employment increased by 8.46% - suggesting that hurricanes create greater labor demand for services. The earnings in the main sectors are however all affected although in different ways. Specifically, hurricanes lead to an increase in earnings for construction and services while reducing the earnings for manufacturing, trade, and finance for affected areas. The neighboring effects for sectors are similar to that of the categories of hurricanes. Belasen & Polachek (2013) also found that hurricane occurrences reduce earnings for trade and services sectors for neighboring areas by 0.83% and 0.44% respectively.

In Mexico, Rodríguez-Oreggia (2013) examined the effect of hurricanes on the returns to skill levels, hours worked, and jobs with social security. Rodríguez-Oreggia (2013) used a triple difference methodology to investigate the effect of hurricanes on the returns to varying skill levels. The study found that the effect of hurricanes on different skill levels have varying effect. Specifically, hurricanes led to greater returns to individual with lower educational levels and formal jobs. The source of this return originated from efforts to rebuild physical infrastructure.

4.3. Data, Sample, and Descriptive Statistics

Hurricane Maria resulted in an increase in recent Puerto Rican migrants moving to the mainland. A recent Puerto Rican migrant refers to an individual who resided in Puerto Rico in the previous year but now resides on the mainland. I examine the labor market effects of Puerto Ricans in Florida and New York who arrived post-Maria. Using the American Community Survey (ACS), I use state-level data for the years 2006 to 2018. The sample starts at 2006 because this is the first available year when the survey collected data with persons in group quarters on a yearly basis and ends in 2018, the last available year.

To evaluate the labor market outcomes of those arriving from Puerto Rico to New York and Florida, I compared the trends of unemployment and labor force participation rates of recent Puerto Ricans in both states to their synthetic counterparts. The unemployment rate used in this paper is the proportion of the recent Puerto Rican migrants in the labor force seeking a job but are unable to find one. The synthetic counterparts for the states are constructed from a weighted average of the states in the "donor pool".

From the ACS survey, Figures 4.1 and 4.2 show the unweighted and weighted number of people in the survey in the US mainland who resided in Puerto Rico the previous year, respectively. While the figures show some level of fluctuations in immigration to the United States, the number of recent Puerto Rican migrants in 2018, post-Maria, is pronounced[16]. Figure 4.1 reports the unweighted number of recent Puerto Rican migrants moving to the US, we see in 2017 this number was just above 600 and for Figure 4.2 that reports the weighted number, in 2017 below 100,000 recent Puerto Rican migrants moved to the US. However, when compared to 2018, we see the

[16] Appendix C shows that Florida and New York saw a large increase in the number of Puerto Rican migrants arriving within the last year. Both the number of people and the possibly unplanned nature of the move may have large implications for their labor markets outcomes.

unweighted number of recent Puerto Rican migrants moving to the US being more than 300 and in weighted terms this is over 50,000; larger than any previous year.

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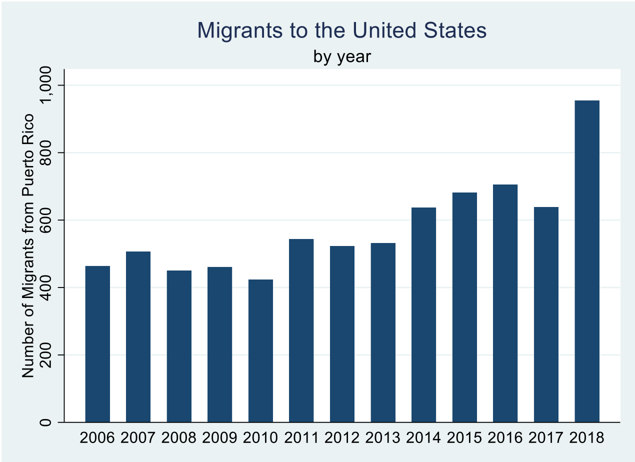

Figure 4.1 Unweighted Number of Mainland ACS Respondents who Resided in Puerto Rico the Previous Year.

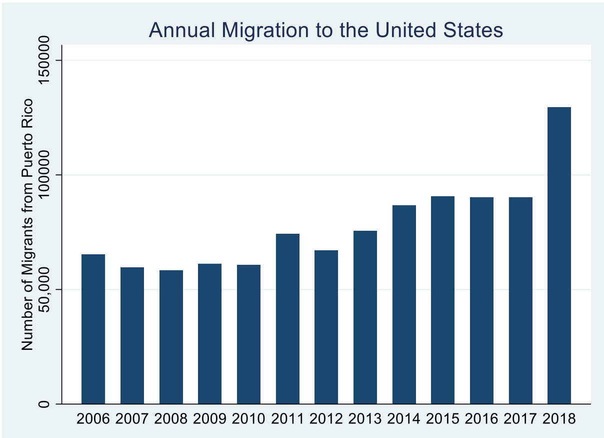

Figure 4.2 Weighted Number of Mainland ACS Respondents who Resided in Puerto Rico the Previous Year

Table 4.1
Unemployment Rate for Recent Puerto Rican Migrants in Florida and New York

	Florida			New York		
Year	Obs.	Percent (%)	Std. Dev.	Obs.	Percent (%)	Std. Dev.
2006	62	11.3	31.9	8	50.0	53.5
2007	85	24.7	43.4	18	22.2	42.8
2008	60	13.3	34.3	20	15.0	36.6
2009	46	32.6	47.4	12	16.7	38.9
2010	40	42.5	50.1	14	42.9	51.4
2011	60	25.0	43.7	18	33.3	48.5
2012	59	27.1	44.8	17	35.3	49.3
2013	57	21.1	41.1	11	54.5	52.2
2014	82	22.0	41.6	12	25.0	45.2
2015	85	15.3	36.2	12	16.7	38.9
2016	90	18.9	39.4	26	15.4	36.8
2017	81	11.1	31.6	16	25.0	44.7
2018	142	13.4	34.2	24	12.5	33.8

Note: This table shows the annual estimates of unemployment rate for recent Puerto Rican migrants in Florida and New York. These estimates are obtained from the ACS and the number of observations is the unweighted number of recent Puerto Rican migrants.

Table 4.1 above summarizes the annual unemployment rate of recent Puerto Rican migrants in Florida and New York. On average we see that the unemployment rate of recent Puerto Rican migrants in Florida ranges between 11% and 42.5%. Not surprisingly, the highest unemployment rate was recorded during the Great Recession. Since then, the unemployment rate of recent Puerto Rican migrants has mainly seen a downward trajectory. The lowest unemployment rate for recent Puerto Rican migrants was recorded in 2017; however, this went up by 2.3% in 2018. In New York, we see in percentage terms, the unemployment rate of recent Puerto Rican migrants is higher when compared to Florida. The highest unemployment rate for recent Puerto Rican migrants in New York was recorded in 2013. The years 2006 and 2010 also recorded significant unemployment rate. However, the unemployment rate has fluctuated since 2006 and unlike Florida experienced a decline in unemployment rate of recent Puerto Rican migrants in 2018 – its lowest record.

In Table 4.2, I present the annual estimates of labor force participation rate for recent Puerto Ricans in both Florida and New York. Table 4.2 shows that overall at least half of the recent Puerto Rican population in Florida are labor force participants. Except for 2007 and 2010, the labor force participation rate for recent Puerto Ricans in Florida remained within 51.7% and 59.7%.

Table 4.2
Summary Statistics of Annual Labor Force Participation Rate for Recent Puerto Rican Migrants in Florida and New York

	Florida			New York		
Year	Obs.	Percent (%)	Std. Dev.	Obs.	Percent (%)	Std. Dev.
2006	105	59.0	49.4	37	21.6	41.7
2007	135	63.0	48.5	41	43.9	50.2
2008	103	58.3	49.6	33	60.6	49.6
2009	86	53.5	50.2	37	32.4	47.5
2010	88	45.5	50.1	45	31.1	46.8
2011	116	51.7	50.2	45	40.0	49.5
2012	108	54.6	50.0	46	37.0	48.8
2013	105	54.3	50.1	42	26.2	44.5
2014	147	55.8	49.8	28	42.9	50.4
2015	147	57.8	49.6	42	28.6	45.7
2016	155	58.1	49.5	43	60.5	49.5
2017	139	58.3	49.5	39	41.0	49.8
2018	238	59.7	49.2	57	42.1	49.8

Note: This table shows the annual estimates of the labor force participation rate for recent Puerto Rican migrants in Florida and New York. These estimates are obtained from the ACS and the number of observations is the unweighted number of recent Puerto Rican migrants.

In 2018, the labor force participation rate increased by 1.5% over the estimate in 2017. In New York, the labor force participation estimates for recent Puerto Rican migrants are generally lower when compared to the estimates in Florida. Only in 2008 and 2016 are the labor force participation rates greater. These estimates show that in the year 2018, when an influx of recent

Puerto Ricans was largest in Florida and New York, we see an increase in recent Puerto Rican migrants either finding employment or seeking work.

4.4. Empirical Methods

In this study, I use the synthetic control method (SCM) to estimate the labor market effects of recent Puerto Rican migrants to New York and Florida. In comparative case studies, the focus is on the occurrence of events or interventions and we often want to assess the impact of the event on some outcome. Abadie et al. (2010) suggest the synthetic control model to assess such events. According to Abadie et al. (2010) the SCM is useful to evaluate comparative case studies for researchers since a unit or two may be exposed to an intervention while this is not the case for the rest.

The synthetic control method, as developed by Abadie & Gardeazabal (2003) and further developed by Abadie et al. (2010), is a data-driven procedure used to construct control groups. The purpose of this method is to utilize a combination of units which improves on the comparison of the unit exposed to the intervention. The method has been applied to study quasi-experimental issues such as crime, terrorism, evolution of GDP, and mortality rate at some aggregate level. According to Abadie et al. (2010) the synthetic control method has two properties that makes it more desirable or appropriate relative to "traditional regression methods". The first is that the method explicitly illustrates the weight that each unit of the control unit contributes to the counterfactual. Second, Abadie et al. (2010) explain it shows the similarities or dissimilarities between the treated unit and the synthetic control units, in terms of pre-intervention outcomes and other predictors of the post-intervention outcomes.

As indicated by Abadie et al. (2010) one problem of comparative case studies that SCM overcomes is the issue of ambiguity. In some case studies it is common for researchers to choose comparison groups based on subjective measures. By introducing a synthetic control group, I make explicit each control unit's relative contribution to the counterfactual of interest. I will also establish, based on the predictors of the post-intervention outcome, whether there are similarities between the affected states and the synthetic control. In this way, synthetic Florida and synthetic New York are meant to reproduce recent Puerto Rican migrants' unemployment rate if Hurricane Maria had not made landfall in Puerto Rico. Similar to Peri & Yasenov (2019), the synthetic counterparts are an estimate of what would have happened if there was no influx. It is important to note that because Florida and New York recorded an influx of recent Puerto Rican migrants post-Hurricane Maria, in the estimation of each, I exclude the other. In addition, there are no data on recent Puerto Rican migrants, in any of the available years, moving to the state of Wyoming. Therefore, the donor pool has 49 states including District of Colombia.

In this paper, the model for assessing the labor market outcomes follows that of Abadie (2020); Abadie et al., (2010); and Abadie & Gardeazabal, (2003). Abadie et al. (2010) assume that there are $J + 1$ regions where the first is exposed to the intervention and the remaining J regions are potential controls which are also referred to as the "donor pool". In Abadie et al. (2010) Y_{it}^N is the outcome of interest prior to the intervention for region i at time t for units $i = 1, \dots, J + 1$ and time period $t = 1, \dots, T$. In addition Y_{it}^I is the outcome of interest that is observed for unit i at time t if unit i is exposed to the intervention over periods $T_0 + 1$ to T; where T_0 is the number of pre-intervention periods. Note that $Y_{it}^I = Y_{it}^N$ if the assumption that intervention does not affect the outcome prior to the implementation period.

Abadie et al. (2010) denote the observed outcome for unit i at time t to be

$$Y_{it} = Y_{it}^N + \alpha_{it} D_{it}$$

Where $\alpha_{it} = Y_{it}^I - Y_{it}^N$ is the effect of the intervention for unit i at time t and D_{it} is a dummy taking the value of 1 if the unit is exposed to the intervention and 0 otherwise. The aim of the synthetic control method is to estimate the $\alpha_{it}'s$ from $T_0 + 1$ to T which is

$$\alpha_{1t} = Y_{1t}^{I} - Y_{1t}^{N} = \alpha_{it} = Y_{it} - Y_{it}^{N}$$

This we know if we estimate Y_{1t}^{N} since Y_{1t}^{I} is observed. If Y_{1t}^{N} is defined by a factor model, then

$$Y_{it}^{N} = \delta_t + \boldsymbol{\theta_t Z_i} + \boldsymbol{\lambda_t \mu_i} + \varepsilon_{it} \tag{4.1}$$

In the above $\boldsymbol{\delta_t}$ is an unknown common factor with constant factor loading across unit, $\boldsymbol{Z_i}$ is a $(\boldsymbol{r\ x\ 1})$ vector of observed covariates, and $\boldsymbol{\theta_t}$ is an unknown parameter with $\boldsymbol{\lambda_t}$ and $\boldsymbol{\mu_i}$ are $(\boldsymbol{1\ x\ F})$ and $(\boldsymbol{F\ x\ 1})$ unobserved common factor and unknown factor loadings respectively. The error term, $\boldsymbol{\varepsilon_{it}}$, is assumed to be a random walk. Abadie et al. (2010) also define a $(\boldsymbol{J\ x\ 1})$ vector of non-negative weights which sums to 1 and produce a convex combination of the variables in the donor pool. That is, the value W is the weighted average of the control regions. The weights are selected in an optimal way such that the synthetic counterparts best reproduce the set of values for the predictors of recent Puerto Rican migrants' unemployment and labor force participation rates prior to the occurrence of Maria. The other states are appropriate control because neither have had migration influx to the proportion as Florida and New York. To assess whether there were any effects a pre-post 2017 change in the outcome variable for state of impact is compared with the pre-post evolution of the synthetic control (Peri & Yasenov, 2019).

Equation (4.1) is similar to the generalized differences-in-difference if we assume $\boldsymbol{\lambda_t}$ is constant (Abadie et al., 2010). However according to Abadie et al. (2010) the factor model "allows the effects of the confounding unobserved characteristics to vary" overtime. This means that $\boldsymbol{\mu_i}$ would still be present. However, under the SCM, the application of the weights to $\boldsymbol{Z_j}$ and $\boldsymbol{\mu_j}$ yield unbiased estimators for Y_{it}^{N}.

The inference of this test is further extended to placebo permutations, which are similar to falsification tests (Abadie et al., 2010; Abadie & Gardeazabal, 2003). The permutations tests involve applying the SCM to each state in the donor pool. This is to determine whether the effect estimated by applying to the state exposed is large relative to another random state.

4.5. Results

Subsequent to Hurricane Maria, thousands of recent Puerto Rican migrants moved to Florida and New York. An inflow this significant has potential implications for their labor market outcomes and other measures of welfare. Using state-level data, I estimate the impact of this internal migration on labor outcomes for recent Puerto Rican migrants. In appraising the effect of recent Puerto Rican migrants movement to the mainland, I am answering the central question of what would have happened to the labor market outcomes of recent Puerto Rican migrants if Hurricane Maria had not occurred. That is, how different was the unemployment rate of recent Puerto Rican migrants after Hurricane Maria compared to Puerto Rican migrants in the US in previous years. To carry out this for Florida, I construct synthetic Florida which is a linear combination of states in the donor pool and resembles Florida in terms of pre-Hurricane Maria predictors.

4.5.1. Recent Puerto Rican Migrants Labor Market Outcomes in Florida

Table 4.3 shows a comparison between actual Florida, synthetic Florida, and the average of the other 49 states. In the Table, I show the averages for the control variables included in the estimation of the unemployment rate effect after Hurricane Maria[17]. Table 4.3 shows us that there is resemblance between Florida and synthetic Florida. The synthetic Florida, which is the weighted average of the other states, shows it serves as a better counterfactual for Florida than the rest of the United States. For example, prior to Hurricane Maria, the average unemployment rate for

[17] I also conduct similar estimation for (dis)similarities between actual Florida, synthetic Florida, and the averages of the other states for labor force participation rates. The estimates not presented here indicate that the labor force participation rate for synthetic Florida is similar to actual Florida. The states that best reproduces recent Puerto Rican migrants labor force participation trends in Florida are Illinois (1%), Louisiana (3.7%), Nebraska (2.6%), New Jersey (11.5%), North Carolina (11%), Oregon (1.8%), Pennsylvania (11.6%), Texas (36.4%), Utah (0.6%), and Virginia (19.8%).

recent Puerto Rican migrants in Florida was higher than the average unemployment rate of recent Puerto Rican migrants in the other 49 states. We see below that synthetic Florida gives more precise values for recent Puerto Rican migrants' unemployment rate and its predictor values. Parallel to matching estimators, this comparison establishes the similarities between Florida and its synthetic counterpart and is thus a more appropriate control group.

Table 4.3

Recent Puerto Rican Migrants Predictor (Covariates) Means for Florida

	Florida		
Variables	Treated	Synthetic	Average of 49 states
Unemployment rate (2014)	0.2195	0.2045	0.0783
Unemployment rate (2010)	0.4250	0.3163	0.0964
Unemployment rate (2006)	0.1129	0.1511	0.0947
Male (%)	0.4970	0.4902	0.3867
Age	34.8807	32.0699	23.1386
Single (%)	0.4818	0.4882	0.4293
Married (%)	0.3379	0.3169	0.1874
Black (%)	0.0494	0.0984	0.0657
White (%)	0.7463	0.6279	0.4693
Hispanic (%)	0.1686	0.1824	0.1501
At most 2 children (%)	0.2709	0.2409	0.1320
At least 3 children (%)	0.0404	0.0358	0.0254
Some high school (%)	0.0907	0.0969	0.0829
High School Graduate (%)	0.2160	0.1856	0.1426
Some college (%)	0.1330	0.1823	0.1458
College graduate (%)	0.2673	0.2582	0.1849

Note: In this table, I report the average estimates for the control variables included in the synthetic control method analysis. In column (2), I report the means for the control variables for the state of Florida. In column (3), I report the means for synthetic Florida, the control group constructed from the weighted average of the other states. In column (4), I report the averages for all control variables for rest of other states, excluding Wyoming and New York.

In Table 4.4, I report the weights of synthetic Florida. These weights suggest that Arizona, Indiana, Louisiana, Michigan, North Carolina, Oregon, Texas, and Virginia are the best states to reproduce recent Puerto Rican migrants' unemployment trends in Florida pre-Maria.

Table 4.4

State Weights in the Synthetic Florida for Unemployment Rate

State	Weights
Arizona	0.095
Indiana	0.073
Louisiana	0.212
Michigan	0.046
North Carolina	0.208
Oregon	0.084
Texas	0.132
Virginia	0.150

In Figures 4.3 and 4.4, I present the trends in recent Puerto Rican migrants' unemployment rate for Florida and synthetic Florida between 2006 and 2018. The vertical dashed line in each of the Figures represents the time of intervention. That is, the year Hurricane Maria struck Puerto Rico. The main interests for each graph are the change in unemployment rate for recent Puerto Rican migrants after 2017 and whether such change is significant. Similar results are presented for labor participation rates in Figures 4.5 and 4.6.

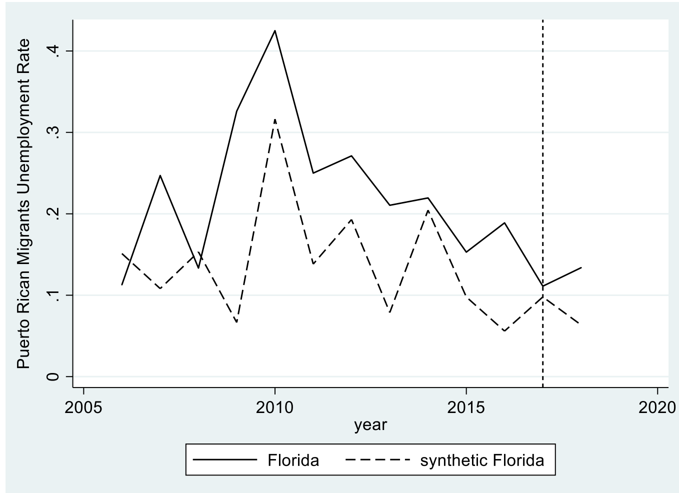

Figure 4.3 Trends in Unemployment Rate for Recent Puerto Rican Migrants: Florida vs. Synthetic Florida

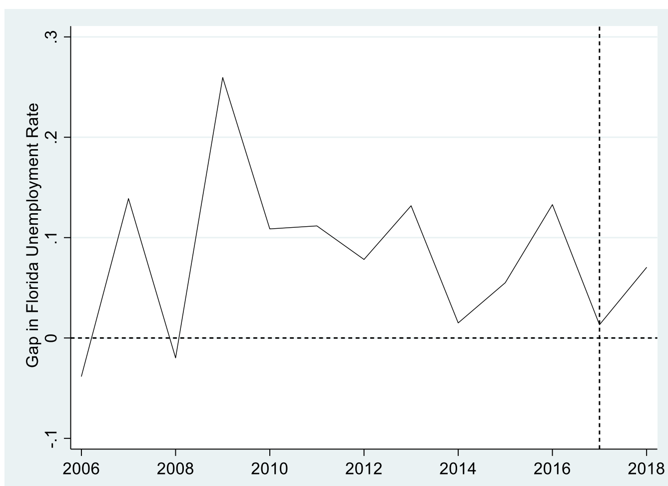

Figure 4.4 Recent Puerto Rican Migrants Unemployment Rate Gaps Between Florida and Synthetic Florida

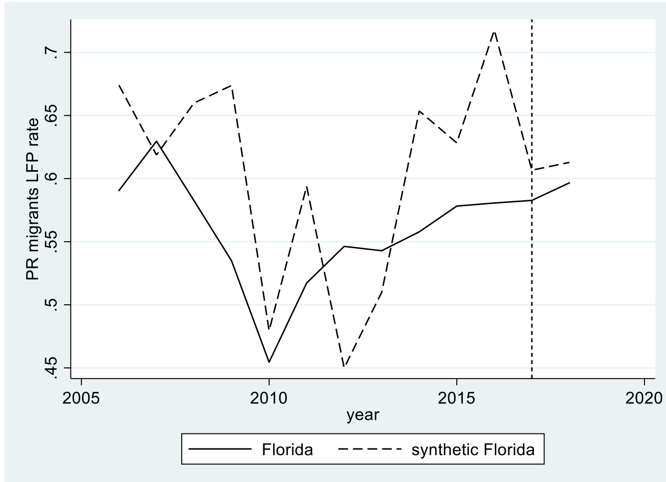

Figure 4.5 Trends in Recent Puerto Rican Migrants Labor Force Participation Rates: Florida vs Synthetic Florida.

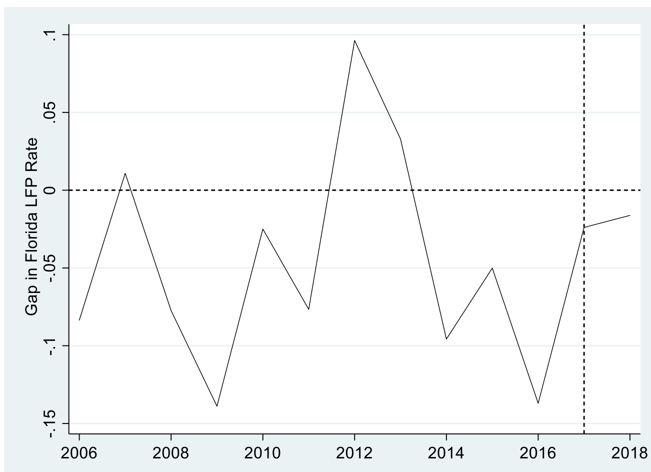

Figure 4.6 Recent Puerto Rican Migrants Labor Force Participation Rate Gaps Between Florida and Synthetic Florida.

The main results of the effect of the unemployment rate outcome for recent Puerto Rican migrants in Florida post-Hurricane Maria are shown by Figures 4.3 and 4.4. In Figure 4.3, I show the trends in recent Puerto Rican migrants' unemployment rate for Florida and synthetic Florida. The effect of the influx is illustrated by the difference between the two curves, shown by Figure 4.4. We see that immediately after Hurricane Maria there is an increase in the unemployment rate for recent Puerto Rican migrants in Florida. A caveat to the results from Figures 4.3 and 4.4, is volatility in the unemployment rate of recent Puerto Rican migrants prior to Maria. Despite the level of closeness between the unemployment rate predictors, as shown in Table 4.3, Abadie et al. (2010) suggest this may be due to a lack of fit and thus the degree of increase in recent Puerto Rican migrants' unemployment rate may not be due to Hurricane Maria. One way to gain better inference of the results presented above is conducting placebo tests. These tests evaluate the significance of the post-Hurricane Maria immigration on the unemployment rate of recent Puerto Rican migrants and compare the gaps of Florida to the gaps for other states in the donor pool.

In Figures 4.5 and 4.6, we see the trends in labor force participation rate for recent Puerto Rican migrants in Florida. Figure 4.5 indicates that there is some volatility in labor force participation trends given by the close trend between actual Florida and synthetic Florida in some years and greater differences in other years. In Figure 4.6, we see how the difference evolves overtime. Figure 4.6 shows in most years the difference between the synthetic counterpart an actual Florida is approximately 10%. One reason for the fluctuation of this trend can be attributed to the small sample. Post-2017 there appears to be not much change in the labor force participation rate for recent Puerto Rican migrants in Florida.

4.5.2. Inference for Recent Puerto Rican Migrants in Florida

According to Abadie et al. (2010) we can draw further inference about the increase in migration post-Hurricane Maria on unemployment rate for recent Puerto Rican migrants in Florida by conducting placebo tests. The aim of these tests is to evaluate the significance of the estimates. To do this I iteratively applied the synthetic control method to estimate the effect of post-Hurricane Maria migration to each state in the donor pool. That is, I conducted the analysis as if one of the states in the donor pool experienced the significant increase in recent Puerto Rican migrants. Following this process, I computed the associated gap estimates of the placebo tests. Figures 4.7 and 4.8 show the gaps for recent Puerto Rican migrants from the placebo tests, where the black line indicate Florida and the gray lines indicate other states in the donor pool.

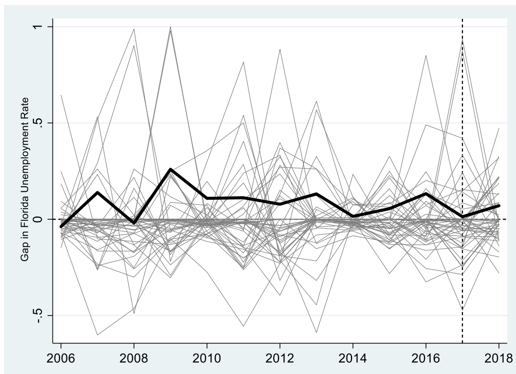

Figure 4.7 Recent Puerto Rican Migrants Unemployment Rate Gaps in Florida and Placebo Gaps in Control States (all states excluding New York and Wyoming)

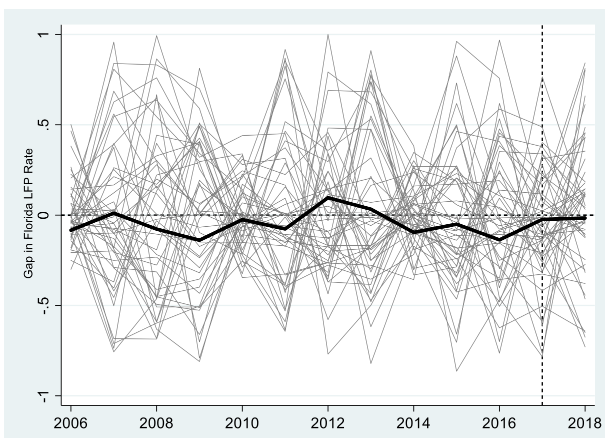

Figure 4.8 Recent Puerto Rican Migrants Labor Force Participation Rate Gaps in Florida and Placebo Gaps in Control States (all states excluding New York and Wyoming)

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Figure 4.7 shows the results from the placebo tests. Each line represents the gap associated with each state. The black line shows the gap in recent Puerto Rican migrants' unemployment rate between Florida and synthetic Florida while the gray lines show the gap in the unemployment rate for recent Puerto Rican migrants between each state in the donor pool and their synthetic counterpart. As Figure 4.7 shows, the estimated gap for Florida prior to Hurricane Maria is lower relative to the distribution of gaps for the states in the donor pool; indicative of a better fit. However, we also see that the gap in unemployment rate for recent Puerto Rican migrants post-Hurricane Maria is not unusually larger than the states in the donor pool. In Figure 4.8, I show the labor force participation gaps between recent Puerto Rican migrants in Florida and other states. As shown the gap for Florida indicate a better fit compared to the states in the donor pool. Post-Hurricane Maria, we see that the trend in labor force participation was not significant relative to other states.

Figure 4.7 also shows that unemployment rate cannot be suitably well-produced for some states in the donor pool by a weighted average of other states. For a clearer comparison of Florida to other states in the donor pool, I exclude states for which their pre-Hurricane Maria mean squared prediction error (MSPE) is at least twice and 1.5 times that of Florida's pre-Hurricane Maria MSPE. The average pre-MSPE for Florida is 0.1145 and the pre-Hurricane Maria MSPE for the other states in the donor pool is 0.1612. This resulted in 9 states being excluded since their pre-Hurricane Maria MSPE is greater than 0.23 and an additional 6 states being excluded because their pre-Hurricane Maria MSPE average is greater than 0.17. The results for excluding states with pre-Hurricane Maria MSPE at least twice and 1.5 times that of Florida are shown in Figures 4.9 and 4.10 respectively. In these restricted placebo tests, we observe that the unemployment rate for recent Puerto Rican migrants, post-Hurricane Maria, is not unusually large relative to the other states. In Figure 4.11, a similar graph is shown for the labor force participation rate where states with MSPE twice that of Florida are excluded. The results remain consistent: Florida has a relatively better fit compared to the other states and the labor force participation rate post-Hurricane Maria does not appear to be significantly affected.

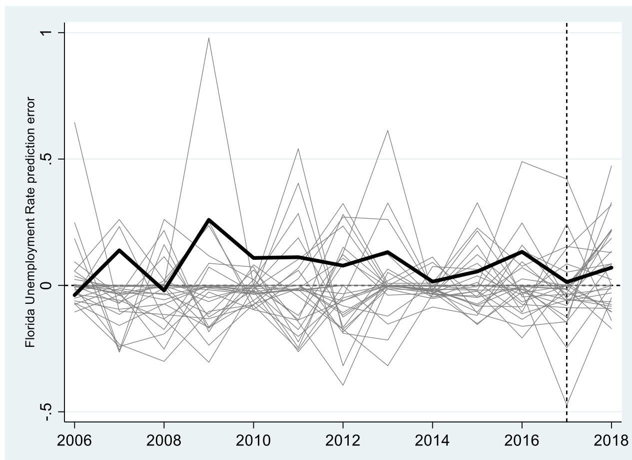

Figure 4.9 Recent Puerto Rican Migrants Unemployment Rate Gaps in Florida and the Placebo Gaps (Excluding States With Pre-Hurricane Maria MSPE Twice That of Florida's).

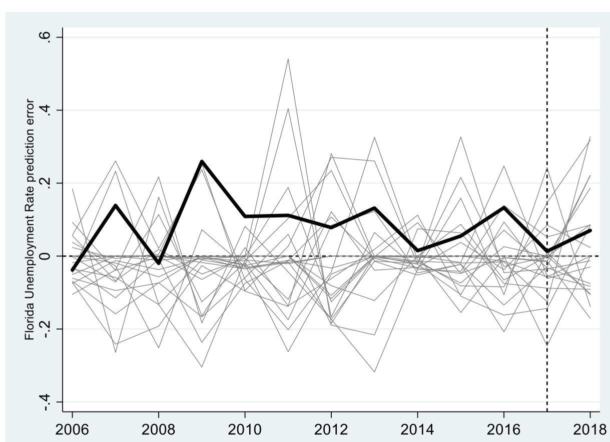

Figure 4.10 Recent Puerto Rican Migrants Unemployment Rate Gaps in Florida and the Placebo Gaps (Excluding States With Pre-Hurricane Maria MSPE 1.5 Times That of Florida's).

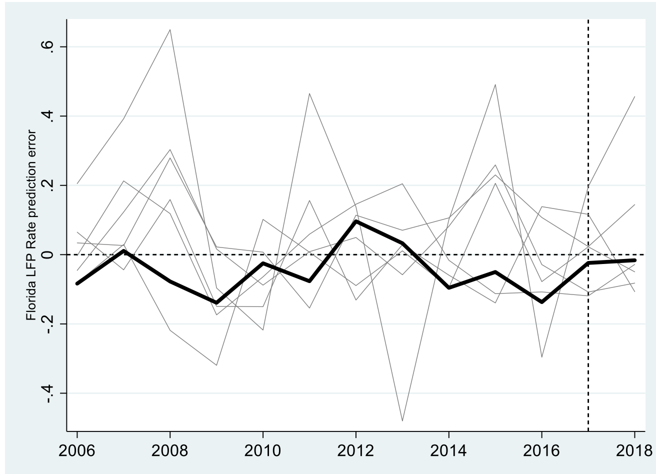

Figure 4.11 Recent Puerto Rican Migrants Labor Force Participation Rate Gaps in Florida and Placebo Gaps in Control States (Excluding States with Pre-Hurricane Maria MSPE Twice That of Florida's).

Abadie et al. (2010) used one final method to evaluate the "statistical significance" for the gap of the state of interest and placebo gaps. In Figure 4.12, I show the distribution of the post/pre-Hurricane Maria MSPE. The purpose of this is to see how the unemployment rate gap for recent Puerto Rican migrants in Florida compares to the gaps from the placebo tests. In the distribution below, the ratio for Florida is not distinct. In Figure 4.12, Florida's post/pre-MSPE ratio is 0.61 and ranks 19th among the states in the donor pool. Under random permutation, the p-value or probability of estimating a post/pre-Hurricane Maria MSPE ratio to the magnitude of Florida's is 19/49=0.39 or 39%. Therefore, we fail to find evidence that the unemployment rate for those arriving after the Hurricane were more likely to be unemployed when they moved in Florida. The results are similar for labor force participation, as indicated by Figure 4.13, with Florida's post/pre-Maria MSPE ranking 34th and p-value being 0.69.

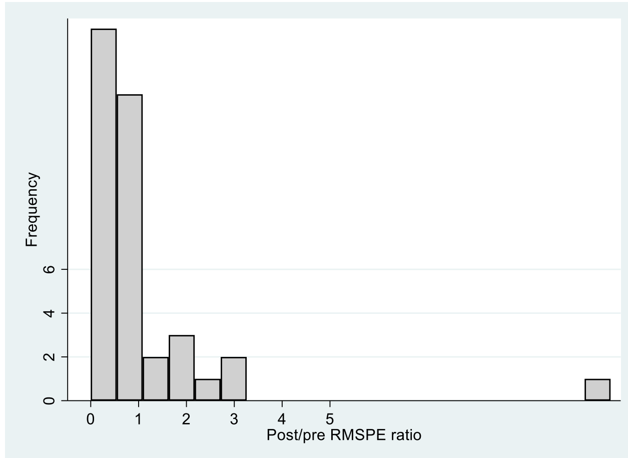

Figure 4.12 Ratio of Post-Hurricane Maria MSPE and Pre-Hurricane Maria MSPE: Florida and Control States (for Unemployment Rate)

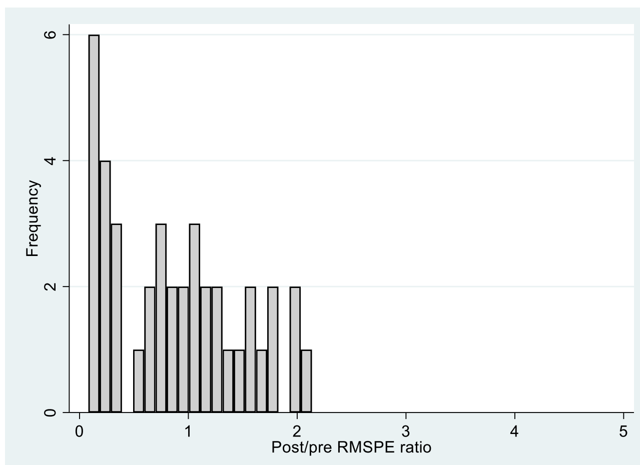

Figure 4.13 Ratio of Post-Hurricane Maria MSPE and Pre-Hurricane Maria MSPE: Florida and Control states (for Labor Force Participation Rate)

4.5.3. Recent Puerto Rican Migrants Labor Market Outcomes in New York

I also perform similar analysis for the state of New York. From Table 4.5, we can see that synthetic New York closely matches the average of the 49 states for all control variables. Similar to the results for Florida, the average of the 49 states is not an appropriate control group. Rather, synthetic New York more accurately reproduces the values of unemployment rate and its predictor variables if New York had not experienced an influx of recent Puerto Rican migrants post-Hurricane Maria[18]. The weights for constructing synthetic New York are shown in Table 4.6.

Table 4.5
Recent Puerto Rican Migrants Predictor (Covariates) Means for New York

	New York		
Variables	Treated	Synthetic	Average of 49 states
Unemployment rate (2014)	0.2500	0.2396	0.0783
Unemployment rate (2010)	0.4286	0.3519	0.0964
Unemployment rate (2006)	0.5000	0.4767	0.0947
Male (%)	0.4786	0.4850	0.3867
Age	35.9214	31.2932	23.1386
Single (%)	0.5759	0.5618	0.4293
Married (%)	0.1930	0.2038	0.1874
Black (%)	0.0912	0.0912	0.0657
White (%)	0.4976	0.5116	0.4693
Hispanic (%)	0.3396	0.3095	0.1501
At most 2 children (%)	0.1582	0.1803	0.1320
At least 3 children (%)	0.0557	0.0513	0.0254
Some high school (%)	0.1666	0.1587	0.0829
High School Graduate (%)	0.1980	0.2140	0.1426
Some college (%)	0.1164	0.1322	0.1458
College graduate (%)	0.1464	0.1229	0.1849

Note: In this table, I report the average estimates for the control variables included in the synthetic control method analysis. In column (2), I report the means for the control variables for the state of New York. In column (3), I report the mean for synthetic New York, the control group constructed from the weighted average of the other states. In column (4), I report the averages for all control variables for rest of other states, excluding Wyoming and Florida.

[18] Similar results were obtained for the predictor means for labor force participation for recent Puerto Ricans in New York. That is, synthetic New York more closely matches actual New York rather than the averages of the other states in the donor pool. The states that best reproduces recent Puerto Ricans labor force participation trends in New York are Illinois (2.9%), Indiana (1.6%), Massachusetts (62.8%), Michigan (5.9), Minnesota (7.3%), Pennsylvania (0.3%), Rhode Island (8.1%), and Wisconsin (11.1%).

Table 4.6
State Weights in Synthetic New York (Unemployment Rate)

State	Weight
Indiana	0.100
Massachusetts	0.715
Michigan	0.121
Oregon	0.065

Specifically, the combination of Indiana, Massachusetts, Michigan, and Oregon best reproduces recent Puerto Rican migrants' unemployment trends in New York.

Figures 4.14 and 4.15 show the main results for the post-Hurricane Maria influx on the unemployment rate of recent Puerto Rican migrants in New York. For Figure 4.14, I show the time trend of unemployment rate for recent Puerto Rican migrants in New York (solid line) and synthetic New York unemployment rate. To understand the impact of recent Puerto Rican migrants movement to the mainland on the unemployment rate we should look at the trends of unemployment prior to Hurricane Maria (i.e. before the vertical line) and the trend after Maria. For Figure 4.15, I show the gap between the two trends. My interest is how well recent Puerto Rican migrants' unemployment rate for New York and synthetic New York matches prior to 2017.

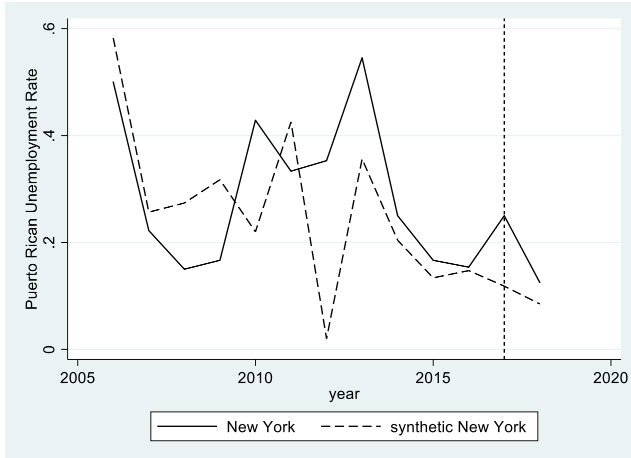

Figure 4.14 Recent Puerto Rican Migrants' Unemployment Rate: New York and Synthetic New York.

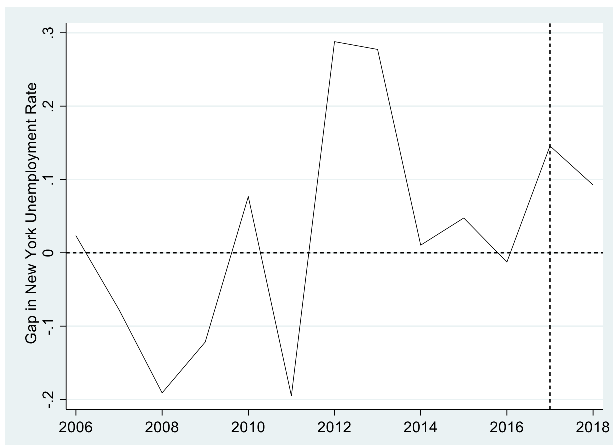

Figure 4.15 Recent Puerto Rican Migrants' Unemployment Rate Gaps Between New York and Synthetic New York.

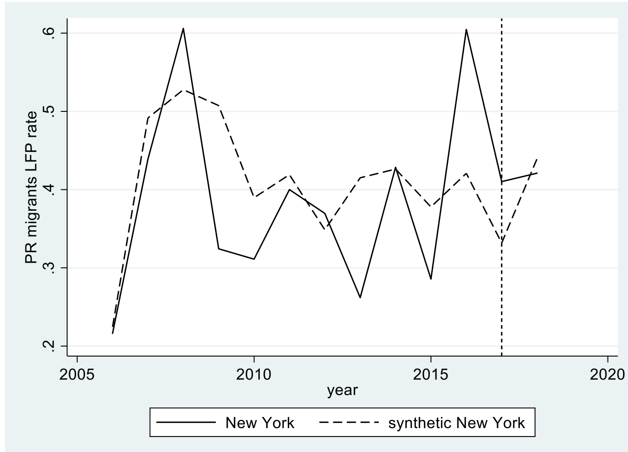

Figure 4.16 Recent Puerto Rican Migrants' Labor Force Participation (LFP) Rate Trends: New York and Synthetic New York.

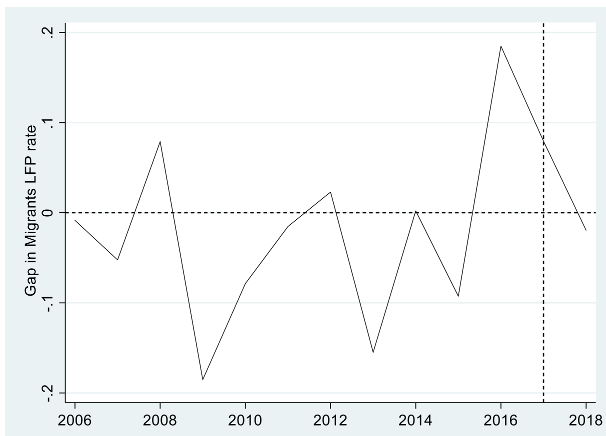

Figure 4.17 Recent Puerto Rican Migrants' LFP Rate Gap Between New York and Synthetic New York.

As shown in Figure 4.15, we see the unemployment rate of recent Puerto Rican migrants decreased post-Hurricane Maria. The results show that unemployment rate of recent Puerto Rican migrants declined by approximately 6%. Figures 4.16 and 4.17 show the trends in labor force participation rate for recent Puerto Rican migrants in New York. Again, the results indicate some volatility. Post-Hurricane Maria, we see a decrease in labor force participation rate.

4.5.4. Inference for Recent Puerto Rican Migrants in New York

To gain some inference of this change in unemployment rate, I evaluate the significance of the estimate using placebo tests. I perform placebo tests for New York, applying the synthetic control method to other states which do not experience as high migration inflow over the period. According to Abadie et al. (2010) these tests provide a formal proof of insignificance if the gaps from the placebo tests resemble that of New York's. If on the other hand, there is a clear distinction in the gap's trends post-Hurricane Maria, we then have significant evidence of Hurricane Maria-induced migration on recent Puerto Rican Migrants' unemployment rate.

The placebo tests of the synthetic control method were applied iteratively to every other state in the donor pool. That is, I iteratively assigned the surge in migration to each of the 49 states. Figure 4.18 shows the results of the placebo tests. In Figure 4.18, the black solid line shows the gap between the unemployment rates for recent Puerto Rican migrants in New York and synthetic New York. The gray solid lines show the gaps for the control states. As shown by Figure 4.18, there appears to be year-to-year volatility in the unemployment rate for recent Puerto Rican migrants as a result of the small sample size. However, the gap estimated for New York is not as unusual as some states in the donor pool. In Figure 4.19, we see a similar effect for labor force participation rate where the gap for New York indicates a better fit compared to the other states in the donor pool.

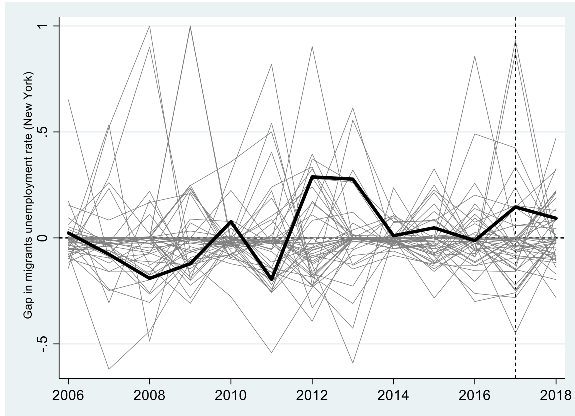

Figure 4.18 Recent Puerto Rican Migrants' Unemployment Rate Gaps in New York and Placebo Gaps.

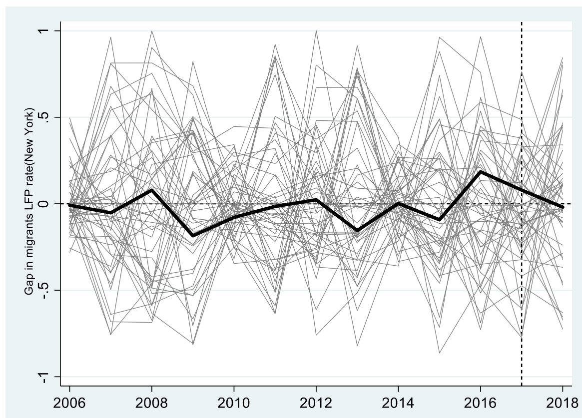

Figure 4.19 Puerto Rican Migrants' LFP Rate Gaps in New York and Placebo Gaps in all 49 Control States.

To gain better inference for the results of New York, I present two other versions of Figure 4.18. These versions show the gaps in unemployment rates for recent Puerto Rican migrants when I excluded states which have pre-Hurricane Maria MSPE values above New York's. The average pre-Hurricane Maria MSPE score for New York is 0.1542 and the average pre-Hurricane Maria MSPE value for other states in the donor pool is 0.1606. Figures 4.20 and 4.21 show the placebo gaps when I excluded states whose pre-Hurricane Maria MSPE values are twice and 1.5 times that of New York's. In Figure 4.20, the placebo gaps are shown when the two states whose average pre-Hurricane Maria MSPE value is at least 0.308. In Figure 4.21, I excluded an additional 7 states since their average pre-Hurricane Maria MSPE value is greater than 0.23. In both Figures we see that the post-Hurricane Maria unemployment rate for recent Puerto Rican migrants in New York is not unusually high relative to the other states. In Figure 4.21, I exclude all states which has a MSPE value that is 1.5 times that of New York. In Figure 4.22, the results indicate that the post-Hurricane Maria labor force participation rate was not unusually large relative to the other states in the donor pool albeit having a better fit compared to the other states.

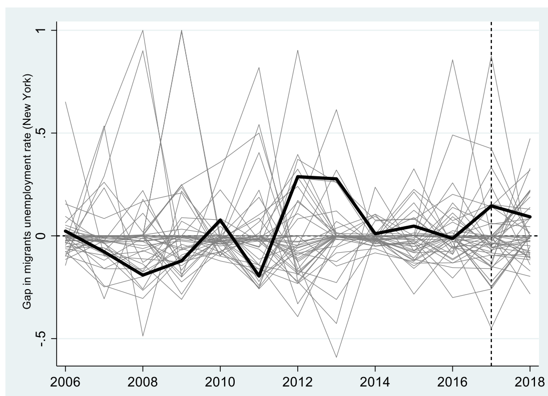

Figure 4.20 Recent Puerto Rican Migrants' Unemployment Rate Gaps in New York and Placebo Gaps (Excluding States with Pre-Maria MSPE Twice That of New York).

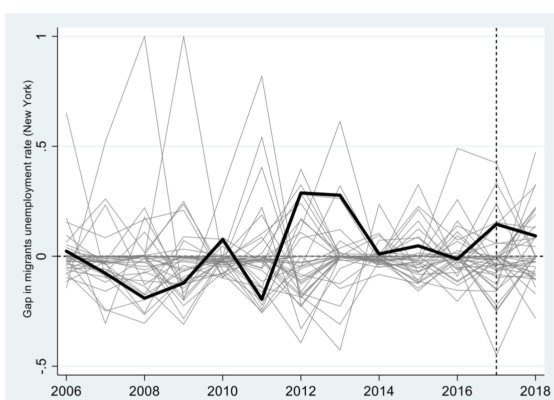

Figure 4.21 Recent Puerto Rican Migrants' Unemployment Rate Gaps in New York and Placebo Gaps (Excluding States With Pre-Maria MSPE 1.5 Times That of New York).

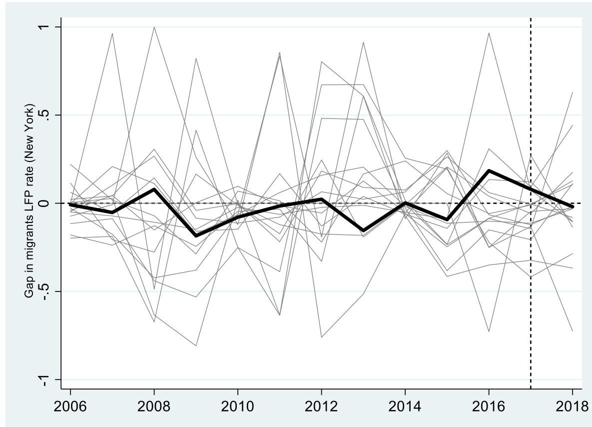

Figure 4.22 Recent Puerto Rican Migrants' LFP Rate Gaps in New York and Placebo Gaps (Excluding States With Pre-Maria MSPE Twice That of New York).

Finally, I show the placebo test distributions in Figure 4.23 for unemployment rate and in Figure 4.24 for labor force participation rate. In our sample New York ranks 21st with a post/pre-MSPE ratio of 0.599. Therefore, the probability of obtaining a post/pre-Hurricane Maria MSPE ratio as high as New York's is 0.42. The results indicate there is no significant effect of the influx on the unemployment rate of recent Puerto Rican migrants in New York. I also tested the effect of the internal migration on the labor force participation rate of recent Puerto Rican migrants in New York. The results are similar to the unemployment effects. In the sample, New York ranks 33rd and has a p-value of 0.67. I do not find a significant impact of recent Puerto Rican migrants' internal migration on the labor force participation rate of recent Puerto Rican migrants in New York.

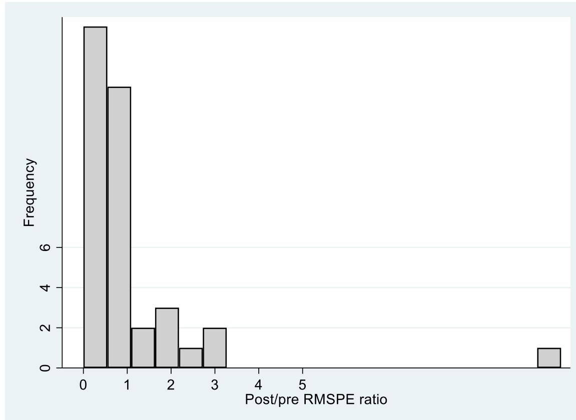

Figure 4.23 Ratio of Post-Hurricane Maria MSPE and Pre-Hurricane Maria MSPE: New York and Control States Unemployment Rate.

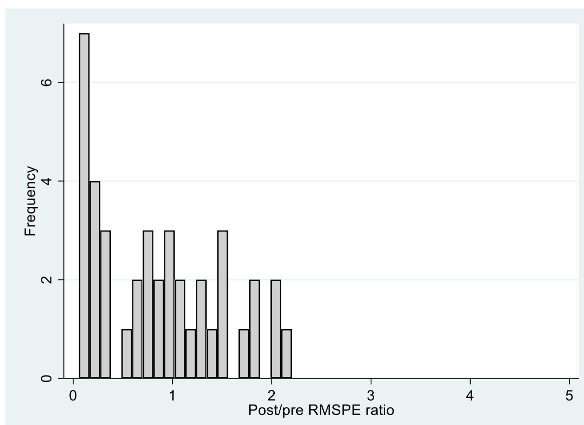

Figure 4.24 Ratio of Post-Hurricane Maria MSPE and Pre-Hurricane Maria MSPE: New York and Control States LFP rate.

4.6. Conclusion

In this paper I evaluated, for the states of Florida and New York, the labor market outcomes of recent arrivals from Puerto Rico after Hurricane Maria. That is, I test if Hurricane Maria, which caused more people to leave the island and likely to leave with little planning affected their labor market outcomes compared to previous years of recent arrivals from the island.

One contribution of this paper is the use of the synthetic control method which has several advantages over other traditional regression techniques. In this paper, I do not find that the labor market outcomes of recent Puerto Rican migrants moving to New York or Florida after Hurricane Maria were worse than earlier recent Puerto Rican migrants. These results suggest that Florida and New York were able to absorb the influx of recent Puerto Rican migrants, likely due to the favorable US labor market at that time. A caveat of these results, however, is the volatility in unemployment rate prior to the period of intervention due to the small sample sizes of this population in the ACS.

In the context of climate change, we see that climate change-related extreme events may push many people to leave their country of origin in pursuit to avoid further damages and achieve income gains. As this study shows their substantial increase in recent Puerto Rican migrants leaving for the mainland. Given predictions of increases in frequency and intensity of climate change-related extreme events, we can expect greater internal migration from Puerto Rico which may have implications for Puerto Rico's economic growth and development.

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APPENDICES

A. Human Subjects Institutional Review Board Letter of Approval

WESTERN MICHIGAN UNIVERSITY

Institutional Review Board
FWA00007042
IRB00000254

Date: February 19, 2019

To: Christine Moser, Principal Investigator
Alvin Harris, Student Investigator for dissertation

From: Amy Naugle, Ph.D., Chair Amy Naugle

Re: IRB Project Number 19-01-29

This letter will serve as confirmation that your research project titled "Climate Change Perception and Adaptive Strategies among Jamaican Farmers" has been **approved** under the **expedited** category of review by the Western Michigan University Institutional Review Board (IRB). The conditions and duration of this approval are specified in the policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note: This research may **only** be conducted exactly in the form it was approved. You must seek specific board approval for any changes to this project (e.g., ***add an investigator, increase number of subjects beyond the number stated in your application, etc.***). Failure to obtain approval for changes will result in a protocol deviation.

In addition, if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the IRB for consultation.

The Board wishes you success in the pursuit of your research goals.

A status report is required on or prior to (no more than 30 days) February 18, 2020 and each year thereafter until closing of the study.

When this study closes, submit the required Final Report found at https://wmich.edu/research/forms.

Note: All research data must be kept in a secure location on the WMU campus for at least three (3) years after the study closes.

Office of the Vice President for Research
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PHONE: (269) 387-8293 FAX: (269) 387-8276
WEBSITE: wmich.edu/research/compliance/hsirb

CAMPUS SITE: Room 251 W. Walwood Hall

B. Countries Included in the Department of State Migration Dataset

Countries	Countries	Countries
Afghanistan	Gambia, The	New Zealand
Albania	Georgia	Nicaragua
Algeria	Germany	Niger
Andorra	Ghana	Nigeria
Angola	Gibraltar	Northern Ireland (DV Only)
Anguilla	Great Britain and Northern Ireland	Norway
Antigua and Barbuda	Greece	Oman
Argentina	Greenland	Pakistan
Armenia	Grenada	Palau
Aruba	Guadeloupe	Panama
Australia	Guatemala	Papua New Guinea
Austria	Guinea	Paraguay
Azerbaijan	Guinea-Bissau	Peru
Bahamas, The	Guyana	Philippines
Bahrain	Haiti	Poland
Bangladesh	Honduras	Portugal
Barbados	Hong Kong S.A.R.	Qatar
Belarus	Hungary	Romania
Belgium	Iceland	Russia
Belize	India	Rwanda
Benin	Indonesia	Saint Kitts and Nevis
Bermuda	Iran	Saint Lucia
Bhutan	Iraq	Saint Vincent and the Grenadines
Bolivia	Ireland	Samoa
Bosnia and Herzegovina	Israel	Sao Tome and Principe
Botswana	Italy	Saudi Arabia
Brazil	Jamaica	Senegal
British Virgin Islands	Japan	Serbia
Brunei	Jordan	Seychelles
Bulgaria	Kazakhstan	Sierra Leone
Burkina Faso	Kenya	Singapore
Burundi	Kiribati	Sint Maarten
Cabo Verde	Korea, North	Slovakia
Cambodia	Korea, South	Slovenia
Cameroon	Kosovo	Solomon Islands
Canada	Kuwait	Somalia
Cayman Islands	Kyrgyzstan	South Africa
Central African Republic	Laos	South Sudan
Chad	Latvia	Spain
Chile	Lebanon	Sri Lanka

Countries	Countries	Countries
China mainland born	Lesotho	Sudan
Christmas Island	Liberia	Suriname
Comoros	Libya	Swaziland
Congo, Dem. Rep. of the	Liechtenstein	Sweden
Congo, Rep. of the	Luxembourg	Switzerland
Cook Islands	Macau	Syria
Costa Rica	Macedonia	Taiwan born
Cote d'Ivoire	Madagascar	Tajikistan
Croatia	Malawi	Tanzania
Cuba	Malaysia	Thailand
Curacao	Maldives	Timor-Leste
Cyprus	Malta	Togo
Czech Republic	Marshall Islands	Tonga
Denmark	Martinique	Trinidad and Tobago
Djibouti	Mauritania	Tunisia
Dominica	Mauritius	Turkey
Dominican Republic	Mexico	Turkmenistan
Ecuador	Micronesia, Federated States of	Turks and Caicos Islands
Egypt	Moldova	Tuvalu
El Salvador	Monaco	Uganda
Equatorial Guinea	Mongolia	Ukraine
Eritrea	Montenegro	United Arab Emirates
Estonia	Montserrat	Uruguay
Eswatini	Morocco	Uzbekistan
Ethiopia	Mozambique	Vanuatu
Falkland Islands	Myanmar (Burma)	Venezuela
Finland	Namibia	Vietnam
France	Nauru	Yemen
French Guiana	Nepal	Zambia
French Polynesia	Netherlands	Zimbabwe
French Southern and Antarctic Lands	Netherlands Antilles	

C. Summary Statistics of Recent Puerto Ricans in the United States (unweighted and weighted)

State Name	Recent Puerto Ricans (2006-2018)	Recent Puerto Ricans (2006-2018 weighted)	Recent Puerto Ricans (2018)	Recent Puerto Ricans (2018 weighted)
Florida	2142	302,358	302	43,985
New York	674	85,772	69	10,580
Pennsylvania	468	79,852	57	8,309
Texas	561	72,953	76	9,684
Massachusetts	497	58,893	61	6,845
New Jersey	376	50,170	32	4,376
Connecticut	286	37,944	39	3,949
Ohio	226	28,889	22	2,210
Georgia	227	26,652	14	1,812
California	201	23,380	13	1,451
Illinois	148	21,134	22	2,992
North Carolina	171	20,680	18	1,658
Virginia	182	20,093	23	1,941
Maryland	108	15,512	21	1,996
South Carolina	109	14,507	20	4,226
Michigan	72	11,867	4	259
Wisconsin	58	11,450	16	2,319
Arizona	99	11,031	12	1,584
Kentucky	56	7,919	11	1,237
Rhode Island	62	7,704	2	736
Washington	63	7,603	6	1,053
Tennessee	65	7,521	14	1,953
Missouri	55	7,409	8	437
Colorado	42	6,724	8	1,434
Alabama	67	6,458	9	1,266
Louisiana	59	6,152	3	311
Indiana	38	5,497	17	3,122
New Mexico	26	5,248	7	1,106
Arkansas	30	5,186	9	1,482
Delaware	22	4,827	0	0
New Hampshire	27	4,355	6	1,602
Minnesota	17	3,720	0	0
Nevada	28	3,312	3	320
Mississippi	40	3,194	2	237
Oklahoma	23	2,856	3	351
West Virginia	24	2,326	0	0
Idaho	14	2,123	6	946

State Name	Recent Puerto Ricans (2006-2018)	Recent Puerto Ricans (2006-2018 weighted)	Recent Puerto Ricans (2018)	Recent Puerto Ricans (2018 weighted)
Oregon	22	2,014	0	0
North Dakota	4	1,980	1	33
District of Colombia	22	1,794	1	46
Hawaii	19	1,758	0	0
Nebraska	14	1,608	4	118
Utah	13	1,546	0	0
Kansas	12	1,087	3	262
Alaska	14	954	3	494
south Dakota	12	833	5	446
Iowa	9	733	0	0
Maine	5	725	0	0
Montana	5	449	3	270
Vermont	3	365	0	0