CLIMATE CHANGE, MIGRATION AND SECURITY

Best-Practice Policy and Operational Options for Mexico

Elizabeth Deheza and Jorge Mora

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Cover image: Tarahumara women and children return by foot to their communities in the mountains after receiving food aid in Laguna de Aboreachi, Mexico, during the worst drought for seventy years. *Photo courtesy AP/Dario Lopez-Mills*.

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Contents

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Advisory Panel

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Susan Martin holds the Donald G Herzberg Chair in International Migration and serves as the Director of the Institute for the Study of International Migration in the School of Foreign Service at Georgetown University.

Previously, Dr Martin served as the Executive Director of the US Commission on Immigration Reform, established by legislation to advise Congress and the president on US immigration and refugee policy, and Director of Research and Programs at the Refugee Policy Group. She is the author of 'Climate Change, Migration and Governance', in *Global Governance*; 'Managing Environmentally Induced Migration', in Frank Laczko and Christine Aghazarm (eds.), *Migration, Environment and Climate Change: Assessing the Evidence*; 'Climate Change, Migration and Development' in Irena Omelaniuk (ed.), *Global Perspectives on Migration and Development*; and 'Environmental Change and Migration: Legal and Political Frameworks' in *Environment and Planning C: Government and Policy* (forthcoming). She co-chairs the German Marshall Fund (GMF) Study Team on Climate Change and Migration, composed of experts and policy-makers from the migration, environmental and humanitarian communities.

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Fernando Aragón-Durand is an international consultant and researcher on risk, disasters, climate-change adaptation and policy for Latin America urban contexts. He holds a PhD in Planning Studies (Development Planning Unit, University College London) and is member of the Intergovernmental Panel on Climate Change (IPCC), working group II, 'Impacts, Vulnerability and Adaptation'. He is also a fellow of the Leadership for Environment and Development Program (www.lead.org). For more than fifteen years, Dr Aragón-Durand has researched the social construction of disasters and risk at policy and community level.

More recently, Dr Aragón-Durand authored the climate change programme for the National Autonomous University of Honduras and the policy report 'Insurance and Climate Change Adaptation in Mexico' for the National Institute of Ecology and UNDP-Mexico. Dr Aragón-Durand co-ordinates the programme on resilience and climate-change adaptation for the Mario Molina Centre, Mexico City. He lectures on environmental history, risk and disasters in the Faculty of Economics of the National Autonomous University of Mexico. He has more than twenty-five years of extensive teaching experience at secondary, undergraduate and graduate level on ecology, urban environment, disaster risk reduction, sustainable development and political ecology in Mexico.

Preface

This academic research was commissioned by the Foreign and Commonwealth Office (FCO) through the British Embassy in Mexico in June 2011 to build upon and mobilise emerging findings concerning climate-induced migration issues, and to deliver practical policy recommendations.

This project follows on from RUSI's previous work on Mexico and Central America, undertaken in 2008–10, which provided a broad academic assessment of the implications of climate change for national security. In the final report, launched in 2010, evidence was presented to support the hypothesis that climate change is expected to have a profound impact on Mexico and Central America; reshaping resource distribution, creating new dynamics of 'winners' and 'losers', and complicating responses to problems of poverty and governance. We argued that these changes have the potential to reshape the physical and political terrain of Mesoamerica, and could have far-reaching repercussions for national and regional security.

Previous work by RUSI highlights that while climate change is not necessarily a direct cause of migration and related security challenges, it will have implications for the movement of people. In contrast to the common conception that migration will be the most likely and most serious consequence of climate change, with potentially large numbers of people migrating long distances, our analysis found that while climate impact can affect the drivers of migration – along with many other push and pull factors – most migration is internal and not likely to be permanent.

During this research project, it was important for us to emphasise the need to expand the definition of national security to encompass social and political stability. In the absence of hostile foreign powers since the late 1960s, national security issues in Mexico have typically been associated with internal social and political turmoil, including armed insurgencies in rural and urban areas and, in recent years, transnational criminal organisations and drug-trafficking organisations, fitting with more traditional definitions of security focused on violence. In contrast, an expanded definition enables analysts to look at the drivers of threats to national security stemming from outside the military sphere; for example, as a potential consequence of issues such as serious organised crime, resource scarcity and pandemic disease.

In our examination of the complex interactions between climate change and security, three conclusions emerged. Firstly, climate change will impact people's ability to meet their basic needs, especially those whose livelihoods depend on climate-sensitive sectors such as agriculture and fishing. Secondly, climate changes will not affect everyone equally, and this has the potential to exacerbate social divisions and tensions. The region is already characterised by significant social divisions, and as the impact of climate change intensifies, the potential to widen these divisions increases – which, depending on how they are handled, could increase risks of social instability. Thirdly, climate change will compound existing challenges around governance and institutional capacity – increasing demand for disaster response and recovery, and the implementation of adaptive measures.

Over the course of our previous research, we found that migration and displacement are often both thought of as the most likely, and potentially the most serious consequence of climate change in this region. It is this which provides the impetus for the current project to conduct a more detailed and quantitative analysis of how climate change will impact migration and the possible implications this may have for security. We already know that while climate change is not necessarily a direct cause of migration and related security challenges, it will have profound implications for the movement of peoples in terms of sources, destinations and routes taken. It is from this premise and under the recommendation of the United Nations Framework Convention on Climate Change (UNFCCC) Cancún Agreement's call for more work to 'enhance understanding, coordination and cooperation with regards to climate change, induced displacement, migration and planned relocation' that our current work begins.

Aims

The current project has several primary aims, ranging from enhancing fundamental academic understanding of the climate-security nexus and the impact of migration in this context, to providing evidence in support of good governance and best-practice policy decisions and implementation in Mexico. The global aim of this work is to contribute to the international evidence base supporting the need for further action to address climate change and forge inter-departmental links across the Mexican government, and foster the development of a 'shared language' to develop national and regional collaboration as well as to elevate cross-party and civil society awareness of the climate-security-migration nexus.

A dichotomy currently exists between policy analysis and scientific research into the impact of environmental change on human migration, with policy commentary often lacking the appropriate data to support its claims and academic research often criticised for being undertaken in institutions in developed countries, far away from the most affected localities.

Bridging this gap, RUSI constructed a partnership with Mexican academics to ensure that all conclusions are strongly evidenced at the local level and are discussed in the context of those issues most important to Mexico today. The qualitative side of this study brings together and critically discusses a large database of literature, complemented by interviews with former and current legislators and government officials, parliamentarians and their aides, former ministers, academics, non-governmental organisations (NGOs), public figures and subject-matter experts in climate change, migration and security in Mexico.

To provide a more robust foundation for these discussions, a quantitative model is also developed to explore the statistical significance of links between climate change and migration. The model provides a platform to fully explore the impact of climate change on migration with outputs at national and regional levels using municipal resolution climate data and demographic data as inputs. The model is not a predictive tool that can give absolute numbers of the migrants and their destinations; however, it does econometrically demonstrate the effect of several key variables (both demographic and climatic) on the decision to migrate internally or internationally. Further developments to this platform could yield even greater detail, reaching outputs on the state level in the first instance and potentially the municipal level.

Policy-makers should view this report as a first step towards the qualitative and quantitative understanding of the relationship between environmental changes, migration and security. Some potential links between these three fields have been demonstrated, but much work has still to be done to provide more conclusive evidence of a link between climate change and migration and its security implications.

Executive Summary

Climate-induced migration (CIM) in Mexico is a complex issue and the future impact of this phenomenon is neither clear nor agreed upon. There is growing consensus that the emission of greenhouse gases (GHG) as a result of human activity is causing changes in temperature, precipitation levels, sea levels and increased extreme weather events.[1] Projections based on data from the Centre for Atmospheric Sciences (UNAM) predict a rise in average temperature of up to 4°C in Mexico by the end of the century, with the greatest warming in the north and northwest. At the same time, precipitation could decrease by up to 11 per cent over the same period.[2] It is evident that the climate is and will continue to change, but how will these changes impact migratory patterns within Mexico and the associated security issues?

The current study begins by reviewing existing literature relevant to the phenomenon of migration, as the factors behind the decisions to migrate are not purely economic, but can include: a desire to improve one's level of education; the search for better social and cultural environments; the search for places with lower levels of violence and political instability; family reunification; and – most relevant for this study – a response to changes in the environment.[3] In relation to this, it has been proposed in recent years that changes in climate could accelerate migration;[4] however, there is still a debate on the complex mechanisms by which a changing climate will affect migratory patterns.

The complexity of migration shows that an individual's decision to migrate is influenced by a large and intricate array of macro-, meso- and micro-level issues. Disaggregating such a complex process into its constituent elements and quantifying their weight upon the decision to migrate is clearly not straightforward. The different dimensions of the debate range from experts interested in the actual quantification of CIM and the possibility of massive flows of refugees crossing borders, to those who criticise these estimates and label them as exaggerations. Empirical work on the topic is starting to suggest that the evidence base behind the phenomenon of CIM is growing, and this increased attention is giving governments the confidence to further support investigation of preventative, rather than reactive, measures. CIM does not constitute a direct 'hard' security threat, but depending on how migrants are received in destination areas, tensions in social or political systems could emerge or be exacerbated; the most exposed systems being labour, water, food, energy supplies and health. CIM may also be seen as an adaptive response and could present significant opportunities, such as income diversification. Migrating as adaptation to slow-onset disasters or rising sea levels could be long or short term, seasonal or permanent, internal or cross-border.

The phenomenon of migration has been a part of the Mexican way of life for a century, with persistently high levels of migration to the US, as well as large movements within the country. Traditionally, the decision to migrate stems from social or economic factors, but there is growing evidence in the literature that there might be a link between climate change, extreme weather events and the decision to migrate in Mexico. Broadly, the impact of climate change on these events can be described by two basic environmental parameters: temperature and precipitation. Despite this apparent simplicity, the decision to migrate is multi-causal, and isolating the effects of climate change on this decision from the effects of economic, social or political issues requires a more sophisticated approach.

In addition to the qualitative investigations in the literature review, this report also attempts to address these challenges by using high-resolution atmospheric data and demographic variables and a quantitative statistical model of the interconnections between climate change and migratory patterns. The model analyses the impact of various factors on the decision to migrate using demographic data sourced from the 2010 Mexican National Census and municipality-resolution climate data generated using internationally accepted models. Our econometric results show that climate variability in temperature and precipitation is a determinant in the decision to migrate both internally and internationally.

Many interpretations can be made from the results of our model, one of which is that the statistical significance of the mean annual temperature (increase in probability of 0.00147) on internal migration is greater than the influence of being male over female (increase in probability of 0.0004). In terms of net migration, an increase in mean annual temperature of 1°C results in an increase of the probability to migrate of 0.0008, with an internal migration probability increase of 0.00147. While the latter probability may be considered marginal, if it becomes real, it could be translated into between 176,400 and 470,400 people by the end of the century migrating internally as a direct result of only increasing temperature (based upon IPCC high scenario predictions of an increase in global temperature of between 2.4 and 6.4 degrees by the end of the century),[5] independent of all other variables that affect the decision to migrate in Mexico. At a regional level, the effects of climatic variables are not homogeneous, meaning that there is differential impact of climatic variables in different regions across the country, but in all cases these climatic variables have a statistically significant link to migration.

In light of these quantitative observations, our investigations consider the competition and security of key resources in Mexico in the context of climate change and migration, providing a comprehensive collection of information derived from in-depth research and interviews with academics, policy-makers and civil society in Mexico. Climate change is a threat for the preservation of resources and infrastructure and should feature in future plans at a municipal, state and national level. The impact of climate change on migration is expected to be wide-reaching; however, our analysis has identified important security issues that require in-depth monitoring and action. Competition over key resources such as water, food, land and energy may arise in places of origin and host areas that are also vulnerable to overcrowding, leading to resource scarcity, heightened tension and, potentially, local conflicts. Without predictive local integration plans, the growth of urban slums may occur. Potential competition between farmers, the energy sector and other industries such as mining and commerce may also arise over key resources like water and energy that are critical to production and manufacturing processes.

Water is a crucial resource for Mexico. Of the total extracted water in Mexico, 77 per cent is destined for agricultural activities, 14 per cent for public supply and 9 per cent for industry, agro-industry, services, business and thermal electrical power.[6] The demand for water has increased in line with economic growth and 104 of the 653 aquifers in Mexico have been quoted as overexploited.[7] Additionally, droughts in some northern areas of Mexico are expected to lengthen and intensify.[8] In terms of migration, Baja California Sur, Chihuahua and Coahuila states are particularly interesting; as these northern states consume large amounts of water, increasing stress upon available water could drive population density away from this region. In support of this, our model – presented in Section II, Tables 7 and 9 – shows us that if the annual mean precipitation were to increase (alleviating water stress) then migration from this northern region would decrease. There is significantly less stress on water availability in the southern region. Therefore, an increase in precipitation does not have the same alleviating effects as in the north, as shown in Tables 8 and 10.

More than 20 million people in Mexico are considered to live under circumstances of food insecurity and between 2008 and 2010 alone, almost 2 million people in Mexico were added to this group.[9] Increasing irregularities in the rainy season brought about by climate change will impact the groundwater level and have a disruptive effect on food production; analysts have estimated that Mexico is losing 400 square miles of farmland to desertification each year.[10] The disruption of cropland can result in under-nourishment of the population, which increases susceptibility to infection, encourages displacement and ultimately could result in permanent migration. It has been estimated that 80,000 farmers have migrated to other destinations as the droughts have severely affected their primary source of income.[11] Congruent with these observations, reviewing the quantitative analysis in Section II, Table 10, we can see that an incremental increase in the mean annual temperature of Durango (in the traditional migration region) has a positive impact on the decision to migrate both internally and internationally. Those communities which will not migrate as an adaptive response will have to put in place resilient practices to overcome the impact of environmental change and degradation.

Electricity production often requires high volumes of water to generate steam and for cooling. Thus, a reduction in the amount of available water in Mexico could severely affect power output. This is also a great challenge for other sectors heavily dependent on water, with the probability that different sectors will compete for this key resource.

Oil installations in Tabasco have played a significant role in the distribution and concentration of people in both rural and urban areas.[12] People have moved towards these destinations for social and economic reasons, irrespective of the threats of regular flooding. The oil industry can therefore be thought of as a pull factor in the context of migration, which, in this case, acts in the opposite direction to those environmental factors exposing individuals to greater risk. If we revert to our model in Section II, Table 10, we can see that the southern group (including Tabasco) shows that an incremental increase in annual mean precipitation will positively impact the decision to migrate, meaning that people are expected to leave the area. This result could be an indication that, although until now the economic pull factors have determined migration patterns, this trend could be affected by climatic forces, in which case it could increase the number of migrants in response to the implicit expulsory factors in climate variability.

This report also investigates the current government responses to CIM and its related issues, with an account of existing strategies and policies that have positioned Mexico among the global leaders in the fight against climate change. We consider the potential impact of further actions and best practice to maintain and strengthen Mexico's leading international position. In the context of CIM, the report takes account of the potential for governmental responses to population movements to either exacerbate or relieve the security situation at the human and state level.

Finally, based upon the key findings of our research and a review of Mexico's current strategy, its strengths and areas for improvement, we have developed a series of recommendations, described fully in Section IV of this report. Our recommendations include:

1. Increase awareness and recognition of climate-induced migration in Mexico

2. Enable more effective co-ordination and management of initiatives on environmental change through a collaborative network of institutions

3. Collect higher-resolution climate and demographic data, as well as ecological degradation and resource depletion data, than what is currently available; and collate this into a national, publicly available database

4. Establish an annual vulnerability assessment; standardise CIM vulnerability indicators, coupled with formal annual assessments at the national, state and municipal level

5. Manage migration opportunities as a potential adaptive mechanism

6. Promote information dissemination of detailed historical as well as current information related to changes in climate, so that people are aware of the dangers in the areas in which they live, improving their ability to respond and adapt.

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I. Introduction

Migration has been a familiar aspect of many human cultures through history. These journeys have been motivated and influenced by myriad factors: from societal collapse and conflict, to the search for less-hostile environments and improved economic conditions. People have also moved from one climate zone to another in search of stability, security and prosperity. For several decades, natural variations in the environment and anthropogenic contributions to climate change have been correlated to the frequency, intensity, spatial and temporal extent of extreme weather and climate events.[1] Anthropogenic effects are commonly associated with increasing temperatures, rising sea levels and changing precipitation patterns, and, as a consequence, are often linked to alterations in migratory patterns and population displacement. If current trends continue and projections made by the United Nations Intergovernmental Panel on Climate Change (IPCC) hold true, the average global temperature is expected to increase by at least 2°C by the end of the century, bringing CIM to the forefront of the international agenda, which may become entirely unavoidable in some regions of the world.[2]

The Phenomenon of Migration

Migration has been a central concern of diverse disciplines, ranging from economics and demography to political science, and, more recently, it has gained considerable importance from an environmental perspective. The primary drivers behind the decision to migrate are intuitively based on a search that individuals make to improve their opportunities.[3] The decisions made on this search highlight the differences between the attributes and opportunities of the place of origin and destination, while also taking the associated costs into consideration.

The literature presents much empirical work on the study of the determinants of migration. In the majority of these studies, migration is considered to take place when people seek better living conditions.[4] Many current theories of migration consider different sets of economic variables in the place of origin that determine the decisions and effects of migration. Within the microeconomic models of migration, Todaro[5] highlights that it is the individual who makes the decision to migrate to maximise their utility in response to expected income differentials between regions. While this model indicates that the only impact of migration is through the labour market, it does not consider that migration entails the flight of human capital (people with education, skills, entrepreneurship and willingness to take risks).

One of the most complete perspectives addresses the question of the choices of migrants by merging the individual-based model with the human-capital theory derived from the work of Mincer[6] and Becker,[7] who establish the central idea that income is determined by an individual's characteristics related mainly to levels of education and experience. When merging these ideas with the individual model, it can be established that the potential wages of migrants in the place of origin and destination are related to the skills of individuals. The incorporation of human-capital considerations in the decision to migrate implies that the individuals selected in this process are those for whom the expected income differential between migration and non-migration is greater than the costs associated with migration.[8]

The new economics of labour migration (NELM) model proposed by Stark and Bloom[9] and Stark[10] assumes that the decisions behind migration go beyond the individual to be characterised by the household. Because the skill-related attributes of household members determine and influence the costs and benefits of migration both for households and for individuals, human-capital theory has been incorporated into the NELM models. However, the household perspective implies the inclusion of individual and household variables – including the assets and the human capital – as characteristic of the migrant household, since these variables influence the costs associated with migration and the income from remittances. The NELM model also focuses on migration as a risk-management strategy, particularly in rural economies without crop insurance.

There are few studies that describe the characteristics of locality as fundamental variables in the decisions to migrate. Some exceptions include Stark and Taylor,[11] whose perspective on the relative deprivation of individuals with respect to other local habitants influences migration; therefore the decision is influenced by the distribution of income in the community.

In addition to the economic reasons outlined above, other factors behind the decisions to migrate can include: a desire to improve levels of education; the search for better social and cultural environments; the search for lower levels of violence and political instability; family reunification; and more recently, environmental factors.[12] In general, existing research on migration has emphasised the social, economic, cultural and political – setting aside factors related to changes in the environment, even in regions heavily dependent on natural resources. This study, however, considers that the environment adds a new dimension to the determinants of migration.

Rural areas of less-developed countries or regions have millions of households that rely daily on the natural resources of their local environments, both as inputs to other productive activities and for direct consumption and livelihoods. Clearly, a decrease in the availability of such resources, potentially as a result of climate change, would have a direct impact on the decisions to migrate. There is growing consensus that emissions of GHG, caused by human activity, are altering the Earth's climate, especially leading to changes in temperature, precipitation levels, rising sea levels and increased frequency of extreme weather events.[13] For this reason, it has been proposed in recent years that climate-related changes can accelerate migration.[14]

There are several efforts in various fields to determine the relationship between climate change and migration from different perspectives, including economic, demographic and social. Undoubtedly, the lack of high-resolution climate data has hindered the ability to integrate a climatic perspective and, in fact, the majority of research related to the determinants of migration does not consider any environmental factors. However, a thorough review of the subject-matter literature reveals that the incorporation of environmental issues into the study of migration is not new.[15] Studies such as the EU-funded EACH-FOR project claim to have found linkages between environmental degradation and human migration in Mexico; for example, soil erosion and changing rainfall patterns in Tlaxcala found to be significant push factors in the decision to migrate.[16]

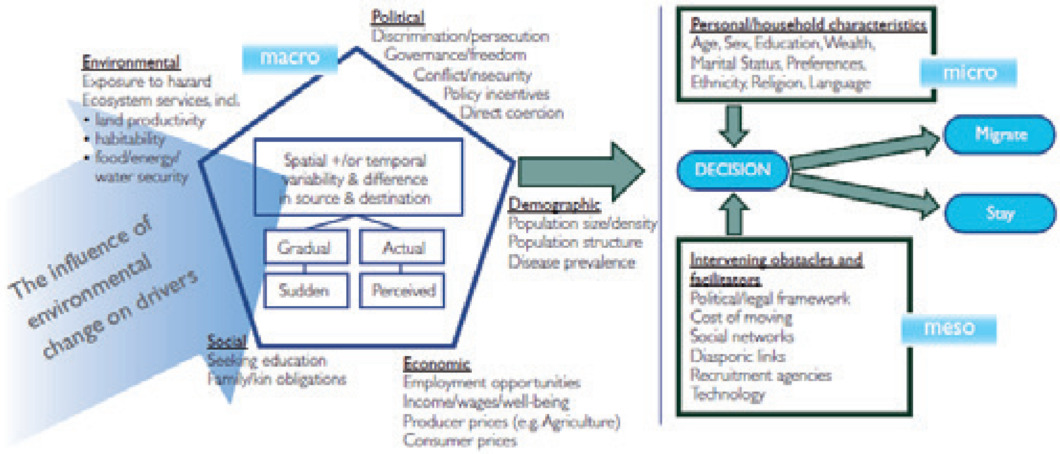
The Complexity of Migration

The phenomenon of migration is complex and interwoven between demographic, social, political, economic and environmental push and pull factors as illustrated in a diagram (see Figure 1) produced by the Foresight programme in the UK's Office for Science within the Department for Business, Innovation and Skills.[17] It is shown that an individual's decision to migrate is influenced by a large and complex array of macro-, meso- and micro-level issues.

Resolving such a complex process into its constituent elements and quantifying their weight upon the decision to migrate is not straightforward. For this reason, it is only in recent decades that considerable progress has been made in unravelling this complexity, and consensus is evolving on the importance of environmental factors behind the decision and ability to migrate. The quantitative analysis detailed in this report confirms that environmental factors – such as precipitation levels and temperature – are determinants of the decision to migrate, which provides the first steps towards a deeper understanding of the influence of environmental factors.

The most significant challenge in developing a model of this complex scenario is to establish, in an appropriate and comprehensive manner, the way these relationships occur at the moment the decision to migrate is made. As shown in Figure 1, there are social, demographic, economic, political and environmental issues involved in this decision. Ignoring any of these aspects could lead to erroneous results – especially today, where variations in climate affect mainly those regions where natural capital is one of the main sources of income.

Figure 1: Conceptual Framework of Drivers of Migration.



The Environmental Context of Migration

The concept of the climate-induced migrant, originally referred to as the 'environmental refugee', was first presented in the 1970s by Lester Brown of the World Watch Institute.[18] Since then, some of the most-cited work in the field has come from two important papers. The first is Essam El-Hinnawi's United Nations Environment Programme (UNEP) paper released in 1985, which provided the first formal definition of the term 'environmental refugee'.[19] The second is a working paper by Jacobson presented in 1988, which offered the first estimation of the number of 'environmental refugees' and highlighted the potential role climate change may play in the displacement of people in the future.[20]

As previously mentioned, over the past two decades the impact of climate change on migration has received increasing interest in the scholarly literature.[21] In 1990, the IPCC noted that the 'greatest single impact of climate change could be on human migration, with millions of people being displaced by natural disasters, shoreline erosion, coastal flooding and disruption of agricultural industries'.[22] The Stern Review then further emphasised this point and warned that 'the effects of climate change could drive millions of people to migrate'.[23] Following this, between 2007 and 2009, migration and displacement were formally recognised in the UNFCCC process,[24] which culminated in paragraph 14(f) on the Cancún Adaptation Framework 2010, a call to 'enhance understanding, co-ordination and co-operation with regards to climate change, induced displacement, migration and planned relocation'.[25] Earlier this year, the latest IPCC Special Report, 'Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation', stated that 'disasters associated with climate extremes influence population mobility and relocation, affecting host and origin communities'.[26] Looking to the future, the IPCC is expected to contribute further to the topic upon the release of a subchapter on CIM in its fifth assessment report in 2014.[27]

There is a general agreement in the literature that changes in climate are impacting human mobility and that this process is set to continue and grow in the future. However, the magnitude of such effects are poorly understood, most likely due to the complexity of the process, the lack of reliable and complete datasets and even the continued debate surrounding basic terminology.[28] As a result of this, projected numbers of people worldwide affected by CIM vary over an order of magnitude with numbers ranging from 25 million[29] to 200 million[30] by 2050.[31] These figures are in agreement with figures released by the International Organization for Migration (IOM)[32] and the Stern Review.[33] However, caution should be taken when quoting such estimates as others have criticised them as simplistic and, furthermore, there is no general agreement on the categorisation of the affected people. Some groups refer to them as 'climate refugees' whereas others adopt their own terminologies such as 'environmental migrants' or 'environmentally motivated migrants'.[34] The IOM defines a climate change migrant as an environmentally displaced person or an environmental migrant as 'persons or groups of persons who, for compelling reasons of sudden or progressive changes in the environment as a result of climate change that adversely affect their lives or living conditions, are obliged to leave their habitual homes, or choose to do so, either temporarily or permanently, and who move either within their country or abroad'.[35]

While the existence of CIM is widely accepted, a consensus has not yet been reached; some researchers reject the notion of CIM and instead describe the process as a 'customary coping strategy'. For them, human mobility is 'a response to spatio-temporal variations in climatic and other conditions, rather than a new phenomenon resulting from a physical limit having been reached'. [36] They postulate that the root of human displacement stems from the effects of human-induced environmental degradation as a result of inadequate environmental management, sustainable development and global development inequalities, rather than from natural hazards and changes in the climate. While human mobility due to environmental changes is not a new phenomenon, anthropogenic climate change combined with extreme weather events are exacerbating these practices, which are also affected by mismanagement and poor allocation of natural and economic resources – all of which may induce people to migrate.

Other contentious issues have also arisen in the field. For example, some researchers called for an international convention to protect 'climate refugees'.[37] However, at present there is little appetite for such a move in the international community.[38] The 2011 Foresight Report, 'Migration and Global Environmental Change', highlights that migration is a multi-causal phenomenon influenced by a complex network of drivers, only some of which may be impacted by climate change. The international authorship of the Foresight Report puts forward the idea that a global framework for 'environmental refugees' is not appropriate as the renegotiation of the 1951 Geneva Refugee Convention and its 1967 protocol may result in the 'loss of important safeguards'[39] for political refugees – an argument this Whitehall Report supports.

A more amenable idea for now may be to build regional understanding and co-operation on the potential impact of CIM, but through existing institutional frameworks. This process could be strengthened by the development of 'a set of Guiding Principles around Climate Induced Displacement, based on the successful outcome of the guiding principles for Internal Displaced Peoples in the late 1990s'[40] and the revision of available work in the field that highlights frequently asked questions about migration and displacement in the context of environmental change[41] as well as gaps in knowledge that need to be addressed.[42]

Environmental Impact on Migration

The majority of the media coverage, and much of the academic literature discussing environmental change and its relation to migratory patterns, highlights the potential consequences of this nexus, but often with a limited evidence base. In fact, there is no conclusive evidence in the literature supporting the conjecture that climate change is a direct or exclusive cause of the movement of people on a large scale. As a consequence, factors indirectly linked to climate change that are capable of inducing the movement of people must be identified.

In this report, climate drivers of human mobility are separated into environmental processes and environmental events.[43] The latter refers to rapid-onset, weather-related natural disasters, such as hydro-meteorological events and mudslides where people are mostly temporarily displaced, followed by a period of rebuilding and recuperation and with an eventual return to the point of origin. These natural disasters that trigger human displacement do not have a causal link with global warming and they may occur regardless of climate change. However, their frequency and intensity may be exacerbated by changes in climate. The displacement of people due to unrest, violence and conflict also falls under this category.[44] Recent data revealed that in 2008 alone, globally 'at least 36 million people were [internally] displaced by sudden-onset natural disasters. Of those, over 20 million were [internally] displaced by climate-related disasters, while almost 16 million were [internally] displaced by non-climate-related disasters'.[45]

Environmental processes refer to indirect, slow-onset events (changes in weather patterns) that contribute to sea-level rises, salinisation of agricultural land, droughts and desertification, water scarcity, and food insecurity – among other things – causing the gradual deterioration of the sustainability of a variety of environment-related livelihoods. Since the early 1990s, some experts have considered migration to be the result of a decrease in agricultural production, water availability and damage to physical infrastructure.[46] In this case, the decision to migrate on a more permanent basis may not be taken immediately; however, where in situ adaptation becomes impossible and the competition over natural resources intensifies, families and entire communities may relocate to safer and more productive areas – most likely within a sub-region and over a short distance rather than long-range migration across international borders.[47] In the same manner, rapid-onset weather-related natural disasters – that may or may not be associated with anthropogenic climate change – will continue to demand the support and relief of temporarily or permanently displaced populations. Additional scenarios that trigger human mobility include 'the destruction of small island states by rising sea levels and areas designated as prohibited for human habitation because of mitigation and adaptation measures or because of a high risk of disasters occurring there'.[48]

CIM has the potential to exacerbate existing challenges associated with the vulnerability of populations in general, and migration in particular. Alternatively, it may also be seen as an adaptation response and could present significant opportunities, such as income diversification and remittance flows. Experts favouring this view explain that 'reducing the barriers to migration on a regional scale and facilitating regional mobility could greatly benefit the migrants [and] the origin and destination countries in the context of climate change'.[49] Migration as adaptation to slow-onset disasters or rising sea levels could be long or short term, seasonal or permanent, internal or cross-border.[50] In the case of rapid-onset disasters, migration as an adaptive measure may be primarily seasonal or temporary, in cases where aid and recovery efforts were not sufficient enough for those affected to remain in their homes. However, and contrary to the notion of migration as an adaptive measure, low-income communities lack financial resources and tend to lose mobility.[51] At the very best, low-income families may relocate locally, while people with greater financial means are in a better position to migrate over a longer range, including across borders. As mentioned above, migration is multi-causal and therefore many important dynamics are pivotal in the decision to migrate, including family ties, gender, religion, community, household differences and landholding.

Once migration has taken place, the resettlement process can be complex and challenging for migrants as well as for the hosts. The much cited Impoverishment Risks and Reconstruction model highlights eight risks that need to be taken into account when considering relocation.[52] These risks include landlessness, joblessness, homelessness, marginalisation, food insecurity, increased morbidity (incidence of diseases), loss of access to common property resources and community disarticulation. Successful resettlement strategies must encompass, as a priority, the establishment of constructive roles for migrants (e.g. in work and education with sufficient standards of living and cultural integration into the host environment).

The main challenge is to organise risk reduction and disaster prevention and provide suitable safeguards to protect migrants. This becomes particularly challenging for fast-growing cities that continue to receive migrants in search of better opportunities, regardless of the extent to which rural-urban migration is caused by environmental change. Rapid urbanisation in densely populated areas may increase the vulnerability of people by concentrating populations in areas of higher risk, such as coastal areas, areas exposed to droughts or flooding, and overpopulated areas vulnerable to future environmental changes. The most exposed areas are likely to be occupied by the poorer levels of society that cannot afford to live in well-protected and maintained neighbourhoods, and it is these people that will bear the brunt of the associated risks.[53] This situation is most evident in urban peripheries, as they are increasingly occupied by both legal and illegal settlements. These human settlements are commonly inhabited by migrants pushed to the peripheries of the city, very poor people that are displaced from city centres and even people who previously lived in city centres but moved out due to soaring rents and the hope of land acquisition in the city fringes.[54] Increased levels of CIM could lead to a rise in the number of informal or illegal settlements, as people move from rural to urban areas in search of work.

Comprehensive analysis of migration and displacement must include both the people who decide to relocate as well as those who remain behind. In light of this, it is important to note that some people have the means but not the desire to migrate (immobile), while others strongly wish to migrate but do not have the financial means (trapped).[55] Many of the worst-affected people are immobile and simply do not migrate, even when their homes are seriously damaged or completely destroyed; many will instead choose to rebuild their homes in the same location. Rural communities and the indigenous population are often more reluctant to leave as their way of life and their roots to their land are sometimes stronger than the desire to look for a better quality of life; they might consider a 'good quality of life' to be what they already have – not what they could find elsewhere. Thus, it can be seen that some resilient people will not migrate even after, for instance, landslides and constant flooding – but only after major disasters which will make their communities entirely uninhabitable and, even then, communities may be rebuilt and become habitable once again.[56] The latter has been suggested by a study on post-Katrina areas in the US, in which the likelihood of an individual or family migrating might be subject to property ownership, secured jobs and better financial means.[57] Climate change might also trap individuals who do not have the financial capacity to respond to these environmental changes: by damaging certain assets, it makes migration financially difficult.[58] For example, reduction in soil quality results in crop failure and reduced income, making it prohibitive to raise the capital necessary to migrate. Thus, poorer people (in rural areas and large cities) – who are most likely to be at risk from climate change – will be less able to migrate staying trapped in potentially dangerous areas that are vulnerable to climate hazards.

The Securitisation of Climate-Induced Migration

There are two main schools of thought when it comes to defining security. Traditionalists define security through its application to military scenarios and the use of force. An alternative approach, adopted here, promotes a broader definition where security is a specific type of politics which can be applied to a wide range of issues. Securitisation is therefore the elevation in importance of a topic above normal with consequences that may have an impact upon national security, therefore legitimising unusual levels of management which may or may not include the use of force.[59]

This definitional nuance is important as the escalation and intensity of the CIM debate has attracted the attention of the wider security sector, with some organisations emphasising the need to respond to CIM with military preparedness and support, stronger border controls and better collaboration between intelligence agencies and states. It has even been suggested that the possibility of climate-induced resource scarcity may lead to conflict, leading indirectly to CIM and exacerbating tensions in host communities.[60] Other studies dispute this, hypothesising that CIM will rarely lead to conflict; although these works do concede that 'unstable urban and rural demographics are related to higher risks of civil war and low level communal conflicts during periods of environmental stress are common'.[61]

Militaries in a number of countries are even declaring climate change and its associated issues as strategic threats, suggesting their governments should develop long-term contingency plans.[62] It is unlikely that issues related to climate change will have a military solution; although the issue appears to have been securitised, it has not and most likely will not be militarised. Any military involvement will come through disaster relief or humanitarian support.[63]

According to some scholars, the recognition that changes in the climate may contribute to increased future migration and the lack of agreement about a concept provided the 'political opportunity for the securitization of CIM and a deeper obsession with border security'.[64] In 2003, a widely cited report predicted that due to environmental degradation, the US will have to strengthen its border controls to 'hold back unwanted starving immigration from the Caribbean islands, Mexico and South America'.[65] Subsequent reports by leading think tanks reported that climate change poses a threat to national security, with CIM as one of the most worrying problems associated with rising temperatures and sea levels.[66] More importantly, some of this research suggested that the movement of hundreds of millions of people could trigger major security concerns and spike regional tensions.[67] In October 2009, the Central Intelligence Agency (CIA) established a new Centre for the Study of Climate Change. In 2010, the Pentagon identified climate change and CIM as security threats for the country in the Quadrennial Defence Review (QDR).[68] In 2009, *NATO Review* also predicted a bleak future for environmental degradation and its impact on migration.[69] Many NGOs and think tanks have contributed to this approach. The Center for Strategic and International Studies (CSIS)/Center for a New American Security (CNAS) report released in 2007 referred to the problem of CIM as one of the major consequences of rising temperatures and sea levels. In an article published in *Defence News* in March 2010, Neil Morisetti (the then-UK climate and energy security envoy) and Amanda Dory (US deputy assistant secretary of defence for strategy) warned that 'climate change-induced water and food scarcity could spur changes in migration patterns in areas where tensions already run high. With 600 million people [worldwide] living less than 35 feet above sea level, rising waters could cause massive displacement of populations, and could devastate crops and property.'[70] There have been calls at an international level for the UN Security Council to take a more prominent position on the issue of climate and resource security and for an envoy to be appointed by the UN Secretary General. In 2011, the Security Council debated climate change and security and came to the conclusion that climate change could exacerbate existing international security threats. Additionally, it stated that environmental changes, such as rising sea levels and the associated loss of land, could have security implications.[71]

Climate-Induced Conflicts

While recent research does not predict the onset of conflict due to trends in global climate, some links have been made between random weather events and outbreaks of conflict.[72] Studies suggest that climate change may exacerbate existing tensions and contribute to new conflicts.[73]

Parallel studies find a persuasive correlation between civil conflicts and the global climate. Based on data for 1950–2004, Solom M Hsiang et al provided the first major link between climate change and civil instability, demonstrating that during El Niño/Southern Oscillation (ENSO) years the probability of a civil conflict commencing in the tropics doubles. Therefore, ENSO may have played a role in more than 20 per cent of all civil conflicts since 1950 – not as the sole cause, but rather as a contributing factor.[74] The ENSO effect can be seen as an example of climate change as a threat multiplier, as high temperatures and the associated droughts may lead to famine and damage to agrarian and non-agrarian economies. Other studies suggest that drastic fluctuations in environmental conditions stress the human psyche, leading to aggressive behaviour and increasing the likelihood of conflict. Concurrent climate-related impacts can reinforce one another to generate 'vicious cycles' of increasing vulnerability that may be difficult to predict and could create ever-worsening challenges.[75] Migration in general could heighten existing social tensions, as locals may resent opportunistic transient migrants. This in turn may give rise to broader political effects; for example, heightened border security and stronger policies to prevent outside groups from accessing a local resource base. Developing countries are especially susceptible to this, due to their geography, dependence upon agriculture, high population growth rate and rapid urbanisation that puts substantial pressure on their already weak infrastructure and overstretched resources.[76]

Mexico: A Migrant Nation

Migration is a defining characteristic of modern Mexico and strongly affects its stability, prosperity and political relations with its neighbours. Migration flows from and through Mexico are not new, yet the push and pull factors controlling these movements are becoming increasingly complex. As the country's history has shown, the migration of people may occur during periods of economic crisis, violence, persecutions, natural disasters and the depletion of natural resources resulting in the loss of fertile lands and the livelihoods of entire communities.[77]

Migration from Mexico – both legal and illegal – has traditionally been associated with people seeking opportunities to improve their economic situation and quality of life, and to sustain through remittances the wellbeing of the families that stay in Mexico, protecting their property and mitigating the effects of unemployment.[78] The US has historically provided such opportunities and it still remains the primary destination for migrating Mexican nationals. As of 2010, 12 million Mexicans live in the US.[79] Estimates from 2002 projected that 22 million Mexicans were expected to live in the US by 2030,[80] but recent statistics from the Pew Hispanic Centre[81] have suggested that net migration between Mexico and the US is currently zero, largely attributed to improved social and economic opportunities in Mexico, an increased number of US border patrols, stricter migration policies in the US, a rise in deportations, weakened US job and housing construction markets and a long-term decline in Mexico's birth rate. Migration also tends to be seasonal (circular migration), with larger northward flows towards the US in the spring and summer and larger southward flows back into Mexico in the fall and winter.[82]

Mexico: A Century of Migration

The flow of migrants towards the US began after the Mexican Revolution (1910) in concomitance with an increasing demand for cheap labour.[83] Migration then took a further boost from the Bracero Programme (1942–64), which helped people from rural areas work in the American agricultural sector. During the 1960s and through to the 1980s, undocumented migration flows coincided with economic downturns in Mexico and Central America.[84] Pull factors such as the agricultural, industrial and service sectors, as well as push factors such as high levels of unemployment and underemployment, had an increasing role in the documented and undocumented movement of people from Mexico to the US.[85] Despite the US adoption of the Immigration Reform and Control Act (IRCA) in 1986 and the economic and liberalisation agreements between Mexico and the US during the 1990s, greater flows of migration towards the US continued, which responded by erecting barriers along the border and reinforcing the US Border Patrol to control migration and the increasing trafficking of drugs from South America. From 1994 to 2001, undocumented migration rose 68 per cent; as an indication of the growth, detentions increased from 979,101 in 1994 to 1,643,679 in 2001.[86] Mexico at this stage became an avid advocate for migrant human rights and offered them assistance through programmes such as the Paisano and Mexican Communities Abroad.[87] This growing population loss was emphasised by former Mexican president, Vicente Fox, who called himself 'the president of 120 million Mexicans – 100 million in Mexico, and 20 million in the United States'.

The promise of opportunity in the US is not a pull factor limited to Mexicans.[88] The same effect propagates throughout Central and South America. As a consequence, the strategic geographical location of Mexico means that it is the subject of the transit migration of people moving from the South towards the US. According to statistics released by the National Institute of Migration (INM) undocumented transit migration coming from Central America (Guatemala, El Salvador, Honduras and Nicaragua) with the US as the final destination shows a rising trend from 1995 to 2005. However, in the period from 2005 to 2010, the trend changes with a 70 per cent reduction in undocumented migration – going from 433,000 to 140,000 border crossing events. In the period 2009–10, the fluxes of transit migration seem to stabilise. During the period 2005–10, deportations fell from 223,000 to 64,000.[89] From 2 January to 23 November 2009, a total of 59,374 people – of whom 26,773 were Guatemalan, 811 Nicaraguan, 9,879 Salvadoran and 21,911 Honduran – were deported from Mexico by land from Gracias a Dios, Carmen and La Mesilla.[90] Around 119,440 migrant workers were deported solely in the two border states of Chiapas and Tabasco.[91] Despite these successful deportations, migration towards the US through Mexican territory is nevertheless expected to continue, but at a slower pace.

Mexico has adopted a tough stance on undocumented immigrants attempting to cross from its Southern border, which greatly contrasts to the solidarity it has with its US-based migrants[92] and recently there has been a reduction in undocumented transit migration through Mexico thanks to tougher migratory policies implemented by Mexican and American government authorities.[93] However, one of the main reasons for this contraction is the increasing violence and insecurity of transit migrants, who are exposed to extortion, kidnapping and even murder inflicted by drug cartels and serious organised crime.[94] For instance, in August 2010, seventy-two migrants from Central America were killed in San Fernando, Tamaulipas as they refused to work for one of the cartels controlling the region.[95]

Mexico has and continues to experience internal migration as people, families and entire communities move from rural to urban areas in search of a better quality of life, more job opportunities, social stability and improved security: all act as motivating factors. Large cities have been a magnet for migration for much of the twentieth century, but in the past two decades, medium-sized cities in the centre, the west and along the northern border have received large numbers of migrants from other parts of Mexico and other countries in Central and South America, contributing to significant demographic changes.[96]

Northern border cities such as Nuevo Laredo, Reynosa, Nogales, Piedras Negras, Ciudad Juárez, Matamoros, Mexicali and Tijuana have experienced, especially throughout the 1990s, a significant increase in their population. For instance, the city of Tijuana located in the state of Baja California, which has the highest immigration among all the states situated in the north of the country, has moved from having a population of 12,271 inhabitants in 1930 to 1.4 million in 2005, which means that its population has increased by over 100 times over the past seventy-five years.[97] Internal migrants towards the northern border usually come from Jalisco, Michoacán, Guanajuato, and, recently, also from poorer and more marginalised states such as Chiapas, Veracruz, Oaxaca and Guerrero.[98] In 2008, around 2.09 million people migrated to northern cities, but in 2008–09 migration flows started to decline, shifting from 2.08 to 1.59 million. International migrants arriving to the border cities declined from 1.18 million to 735,000; and Mexican migrants arriving from the south to the north declined from 902,000 to 835,000.[99]

According to statistics released by the National Institute of Statistics and Geography (INEGI) for 2005–10, 3.3 million people 5 years or older are living in an entirely different location than their residence of June 2010.[100] Recent data[101] show a decline in the flows of migration towards the north of the country, yet many border cities remain overcrowded and migrants are encountering problems in finding appropriate housing and job opportunities. This is largely due to the declining productivity of manufacturing operations (*maquiladoras*), the main industry in the region – now the second wave of *maquiladora* expansion has moved to the southern state of Yucatán.

The current wave of violence in Mexico is also a factor pushing families and entire communities to flee to nearby and safer cities[102] and to even seek political asylum in the US,[103] a clear example of displacement due to violence. The Internal Displacement Monitoring Centre of the Norwegian Refugee Council estimates that in 2011 approximately 140,000 people were displaced by drug cartel violence in Mexico.[104] The Autonomous University of Ciudad Juárez has reported that the city saw 24,500 people displaced in the same year, adding to around 115,000 already displaced since 2007.[105] A study in 2011 from the Department of Government at Harvard University reports this figure to be closer to 264,693.[106]

The polling firm Parametría revealed in a survey conducted in 2011 that forced displacement is one of the consequences of the growing insecurity.[107] Of those who moved residence in Mexico over the past five years, 17 per cent were reported to have moved due to drug cartel violence, which accounts for 2 per cent of the total population (or 1,648,387 citizens) above 18 years old. These displaced people largely come from Tamaulipas, Chihuahua, Michoacán, Nuevo León, Durango, Guerrero and Sinaloa.[108] In certain circumstances, some displaced people have had the opportunity to return. In Tamaulipas, about 400 people were reported to have returned in 2011 due to an improvement in the security of their native communities.[109] Similar results have been observed in Ciudad Juárez as a result of the wide scope of actions of the 'Todos somos Juárez' ('We are all Juárez') strategy, implemented during 2011 and 2012 by the state and federal governments, with international aid, to reduce violence and to restore social fabric in certain areas.[110] Some programmes associated with this strategy – including extended school days, the registration of ten of thousands of unplated cars, the new criminal justice system as well as greater level of organisation, such as the Security Committee of Ciudad Juárez (Mesa de Seguridad de Ciudad Juárez)[111] – are having some positive results.[112]

Criminal activities such as extortion and kidnapping cause a deep fear among citizens. This fear is the primary driving force behind communities deciding to relocate to safer areas, which in turn increases pressure on jobs, food, water and resources; a situation that could lead to unrest and further crime in destination areas if not managed properly by the relevant authorities.

Summary

It is increasingly accepted that a link may exist between climate change and migration; however, there is still a debate on the ways that a changing climate will affect migratory patterns. The different dimensions of the debate range from experts interested in the actual quantification of CIM and the possibility of massive flows of refugees crossing borders, to those who criticise these estimates and label them as exaggerations. A well-established cluster of academics, decision-makers and media have widely accepted climate change as a driver of threats to security, as it has the potential to threaten the stability and prosperity of states and the movement of people. They have also reconsidered the definition of security, shifting from traditional perceptions to encompass social and political stability and the wellbeing of people. Considering climate change as an additional push factor for local and transnational human mobility further complicates a country's border policy.

Thus, while this report supports a more inclusive definition of security and puts human security at the centre of its research, it does not advocate the strengthening of borders to limit 'massive' flows on CIM as 'migrants driven by climate change are not coming to the border nor to transit states in enormous numbers, nor are they expected to do so in the decades to come.'[113] This last point is reinforced by RUSI's previous work, which highlights that 'climate impacts can affect the drivers of migration, along with many other push and pull factors, but most migration is internal and not likely to be permanent.'[114]

Finally, CIM does not constitute a military threat, but depending on how migrants are received in destination areas, tensions in social or political systems could emerge or be exacerbated; the most exposed systems being labour, water, food, energy supply and health. If unemployment and hunger generate temporary or permanent migration, this may drive down wages in destination areas, as undocumented migrants may be prepared to accept lower pay. However, it should also be noted that most governments do not recognise a direct link between CIM and security, perhaps due to a narrow traditional definition of security, or perhaps the complex secondary effects that are not fully understood or appreciated.

Governments are reluctant to acknowledge or accept responsibility for CIM. This could lead to a formal petition from the Global South to be compensated, putting most of the focus on industrialised nations[115] and adding further pressure to an already fragmented coalition of nations calling for the reduction of GHG emissions and the continuation of the Kyoto Protocol. However, empirical work on the topic is starting to suggest evidence base behind the phenomenon of CIM is growing and is giving governments the confidence to further support this work, as well as future investigations into the adoption of the necessary measures that are preventive rather than reactive.

Migration has been a part of the Mexican way of life for the past century, with persistently high levels of migration to the US, as well as large movements of people within the country's borders. The volume of migration is impacted by a number of physical, social, political and economic factors, including climate change, civil unrest and violence and their associated security challenges. Traditionally, the decision to migrate stems from social or economic factors, but there is growing evidence of a link between changing climate and the decision to migrate. Both socioeconomic and environmental scenarios, and their relationship with migration, are of paramount importance to model in future work.

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II. An Empirical Model of Climate Change and Migration

Climate Change and Migration in Mexico

The relationship between climate change and population movement in Mexico is complex. It is important to first review the relevant literature about climate change in Mexico; to understand its major implications and how they stand in the current environmental context. Only once this is fully understood can secondary impacts, such as that on migration, be considered with confidence.

A consensus is forming in the scientific community that man-made GHG are contributing to and exacerbating naturally occurring changes in climate.[1] Over the course of the last century, the average temperature of the Earth has increased by 0.75°C and over the last quarter of a century, the rate of global warming has accelerated by more than 0.18°C per decade.[2] Projections based on data from UNAM predict a rise in average temperature of up to 4°C in Mexico by the end of the century, with greatest warming in the north and northwest. Precipitation is predicted to decrease by up to 11 per cent over the same period.[3] The effects of climate change are expected to vary from one region to another. For instance, the tropics are expected to experience more frequent rainfall and deserts are likely to experience further increases in temperature and a coincident decline in precipitation.[4] The World Health Organization (WHO) reports that by the 2090s, 'climate change is likely to widen the area affected by droughts, double the frequency of extreme droughts and increase their average duration six-fold'.[5]

Severe weather conditions and natural hazards are not a new phenomenon for Mexico, as it has been exposed to climate-related hazards and severe hydrological events throughout its history. Mexico was ranked forty-ninth worldwide in the Germanwatch Global Climate Risk Index, 1991–10.[6] Natural hazards are known to be exacerbated by extreme weather events, such as those resulting from the El Niño/Southern Oscillation (ENSO) phenomenon that alters rainfall patterns, leading to intensive rain, which produces landslides and floods. The effects of fluctuations associated with ENSO may also lead to severe droughts, resulting in serious deficits in reservoir levels,[7] shortages in rain-fed agriculture,[8] reduction in water quality, and many forms of water pollution worsening.[9]

Mexico is exposed on both coasts to hurricanes originating in the Pacific and Atlantic oceans. According to Maplecroft's 'Climate Change Vulnerability Index' for 2011, most of Mexico, and particularly the coastal regions, face 'high' to 'extreme' risks from climate change.[10] Complementary studies predict that Mexican coastal states are already vulnerable to changes in coastal erosion, saltwater intrusion, storm surges and rising sea levels, particularly in low lying areas of the Gulf Coast and the Caribbean.[11] As a result of these observations, climate change poses a very serious risk for Mexico, with 60 per cent of the population and sixty of Mexico's seventy largest cities being located on the coast.[12]

Figures from the World Bank show that between 1997 and 2006, economic losses from storms and floods averaged 0.17 per cent of GDP, and 3.5 million people were directly affected by hurricanes in this period.[13] More recent data show that in 2010, a total of more than 1.4 million people were affected by natural disasters in Mexico.[14] A great proportion of this total was the damage and losses that Mexico suffered during the passage of Hurricane Alex, which hit the northeastern states of Tamaulipas, Coahuila and Nuevo León in July of the same year, leaving thousands of people without electricity, water and shelter. The most evident damage was in the city of Monterrey; as its governor declared, '[the city] collapsed due to the strongest ever natural disaster that hit the region'.[15]

Rising sea levels could render coastlines uninhabitable, damage or destroy industrial infrastructure, or overstretch local authorities. These factors combined would contribute to displacement flows, and ultimately the migration of people, away from coastal regions. The Gulf of Mexico has been highlighted as a region generally at risk from rising sea levels, which is a concern as the Gulf possesses eight of the ten major fishing ports and two industrial ports. On the Pacific coast, the port of Manzanillo, Mexico's busiest port, handles over 25 million tonnes of goods annually[16] and faces the largest potential economic losses from rising sea levels, as it would become increasingly difficult to access and navigate. Other areas that have been highlighted as particularly susceptible are the Yucatán Peninsula (including Cancún) on the Caribbean coast of Mexico, and other coastal zones such as Veracruz, Ixtapa and Cozumel.[17]

The greater intensity and variability of precipitation is predicted to increase the risk of flooding.[18] Floods pose serious security risks and may cause death through drowning and fatal injuries, contaminate clean water supplies, and foster vector-borne diseases. Data from Mexico's National Meteorological Service (SMN) suggests drought periods are being extended and intensified across the country; not just in the arid and semi-arid regions of the north and northwest, but also in the south, which has historically been more humid. The arid and semi-arid regions are more vulnerable to land degradation including desertification, deforestation and soil erosion as the severity of droughts will increase with higher temperatures and greater variations in rainfall.[19] In 2011, 80 per cent of Mexican territory was affected by some kind of drought and 40 per cent by severe droughts.[20] The states most affected by droughts have been Durango, Chihuahua and Coahuila, and then Nuevo León, Zacatecas, San Luis Potosí, Aguascalientes and Guanajuato; looking at the magnitude of droughts, Baja California, Sonora, Sinaloa, Querétaro, Hidalgo and Tlaxcala should also be included in this category.[21] Though droughts have been a recurring event, because they are difficult to detect at an early stage, policies and actions taken are often reactive rather than pre-emptive.

The impact of climate change on agriculture and other water-demanding industries is expected to come from the major climate-related drivers of migration, impacting the local economy and the livelihoods of agricultural families and their businesses. As explained in the previous section, extreme weather events may cause sudden and collective displacement of people. This is an immediate but temporary response to preserve the wellbeing and survival of the affected communities. However, if these changes are slow-onset events, human mobility may be planned and permanent.

Research has suggested that in Mexico, climate change is affecting human mobility in both the hot, dry northern states and the wet, tropical southern states. Some already populous regions that are attractive to migrants have developed, or are predicted to develop, vulnerabilities associated with climate change that could be exacerbated by the increased concentration of people upon arrival of additional migrants – such predictions, made for 2025, highlight Baja California and Chihuahua as the most vulnerable states due to their high temperatures, low rainfall and high consumption of water and energy. Midwest Jalisco, Guanajuato, Michoacán, the State of Mexico and Puebla were also determined to be vulnerable locations, but to a lesser extent. Veracruz and Chiapas are thought to have lower exposure to climate change, and precipitation may be observed to increase, alleviating water, energy and food stress.[22] In contrast to this observation, other studies present evidence that winter temperatures have been steadily rising in central Veracruz while at the same time precipitation has been declining, leading to significant decreases in coffee production, the main crop in the region.[23] According to a 2008 study conducted in two communities in central Veracruz, 28 per cent of households interviewed reported that a household member had migrated during the previous five years, coinciding with the coffee crisis (1999–2003); 60.9 per cent of these migrated to the US and the others went to regional or national destinations.[24]

A study conducted through the European Commission's EACH-FOR project in the rural areas of Sierra and Soconusco in the state of Chiapas[25] shows that the elimination of subsidies, growing competition and unstable consumer prices, combined with the frequent passage of destructive hurricanes and countless tropical storms (leading to increased legal and illegal logging, which in turn can trigger large-scale flooding and landslides), are accelerating the decision of small-scale farmers to migrate from the affected regions.

Temperature is one of the primary climate measurements that correlates with a host of socioeconomic problems related to climate change. A study conducted for the World Bank in 2008[26] revealed that inhabitants who live in communities experiencing higher-than-average temperatures during spring and autumn have an increased probability of migration. However, the probability of migrating within Mexico is lower for inhabitants who live in communities experiencing higher-than-average temperatures during the summer. While tourism may favour slightly higher temperatures, the impact on agricultural industries that rely on stable environmental conditions can be problematic. One investigation determined that an increase in temperature which produces a 10 per cent reduction in crop yield will see a movement of approximately 2 per cent of people from Mexico to the US.[27]

Changes in climate influence fundamental requirements for health such as clean air, safe drinking water, sufficient food and secure shelter.[28] Most health consequences related to climate change are indirect and result from the environmental, ecological and social impact of a changing climate.[29] Weather fluctuations in Mexico impact food yields, water supplies, patterns of infectious[30] and vector-borne diseases,[31] and the displacement of people.[32]

High temperatures combined with torrential rains provide the perfect environment for the contamination of water and food that may result in outbreaks of diarrheal diseases such as cholera that can prove fatal to children and the elderly.[33] Many major killers such as diarrheal diseases, malnutrition, malaria and dengue are extremely sensitive to climate.[34] According to the WHO, in 2004 climate change was already responsible for 3 per cent of diarrhea, 3 per cent of malaria and 3.8 per cent of dengue fever deaths worldwide. It attributes 0.2 per cent of 2004 deaths to climate change, of which 85 per cent were children.[35] Further, lack of access to safe drinking water is a major cause of morbidity and diseases. According to the WHO, 2.2 million people die each year from diarrhea, mostly infants and young children. As the WHO highlights, higher temperatures and too much or too little water can each facilitate the transmission of diarrhea.

Sustained high temperatures (heatwaves) have a direct effect on health security in Mexico, increasing vulnerability to health problems, especially of the elderly, who are expected to make up 12 per cent (17,491,716 people) of the total population by 2025. [36] Some studies even suggest that heatwaves also pose a threat to the security of individuals as well as entire communities by increasing the incidence of violent crime.[37] Another important effect is the emergence of mental-health problems due to the impact of climate change on living conditions of populations, derived from lower agricultural income, displacement or post-traumatic effects once a disaster has occurred.[38] Climate change will therefore alter population health, patterns of death and disease, social stability and geopolitical security[39] by amplifying existing health risks, rather than creating new ones.[40]

Changing rainfall patterns are causing more frequent and more severe droughts in parts of Mexico. Small-scale farmers that depend on rain-fed agriculture will be severely impacted by the increasing irregularity of rainfall.[41] To this effect, a World Bank report[42] found that inhabitants of communities that experience higher-than-average rainfall during summer and winter will most likely not migrate. However, if precipitation is above average during autumn, then the probability of migration will be greater once again. Western Tlaxcala in central Mexico is a prime example of these trends:[43] with the rainy season now starting a month-and-a-half later than twenty years ago, many local farmers have been pushed to migrate. Soil depletion and desertification also affect the agricultural sector in Tlaxcala and are directly linked to changes in precipitation patterns. EACH-FOR found that market liberalisation in the 1990s and declining rainfall led to lower farm incomes, pushing some individuals to migrate, a problem that is more acute in poorer regions of the country.[44]

Despite the detrimental effects outlined above, climate change may make other areas more attractive for human settlement. For example, some communities may benefit from altered patterns of rainfall that bring increased volumes of precipitation to areas that were previously affected by water shortages – assuming the infrastructure to manage it is available.[45] This would constitute a significant pull factor for communities in search of arable land and an ample water supply.[46] Such a scenario is highly likely in Mexico, as currently the majority of the irrigation infrastructure is concentrated in the north, while the land that will be more suitable for agriculture over the next twenty years lies in the south.[47] This is illustrated by recent acquisitions of arable land in southern Mexico by maize-producing organisations that have existing agricultural interests in northern Mexico.[48]

One study by the Institute for the Study of International Migration assesses the complex interconnection between environmental changes and migration in two semi-arid, traditionally emigrant states of Mexico (Jalisco and Zacatecas). It finds that migration predominantly to the US, but also to Mexican urban areas, has been an adaptive mechanism of local communities and households to manage climate variability and diversify incomes, helping the rest of their families to remain in place. Nevertheless, 'the direct and determinative causal linkages between climate change and migration were difficult to identify. Rather, environmental change is one factor (of many other push and pull factors) in migration decisions'.[49] The study concludes that Jalisco and Zacatecas have seen population movements prompted by persistent drought cycles and that poor development planning was exacerbating problems including deforestation and poor water quality.

Town leaders also confirmed that the support of the Mexican Diaspora allowed many families to remain at home while rebuilding, helping them with reforestation and other sustainable development programmes, enabling them to adapt to environmental change. Thus, understanding migration patterns and strategies is crucial to assessing the impact of future migration caused by desertification due to climate change.

Modelling the Relationship between Climate Change and Migration in Mexico

There are only scattered quantitative data and analyses that firmly support a proposed linkage between climate change and migration. This chapter presents an overview of a new multinominal logit model (MLM) developed specifically for the current investigation and uses demographic data from a recent national census in Mexico, together with detailed climate data, to rigorously probe the influences that climate variables have on migration in Mexico. The MLM identifies key variables and their ability to influence the decision to migrate, whether within a country's borders (internal) or across them (international). A detailed description of the approach may be found in Appendix B; a narrative summary is presented here.

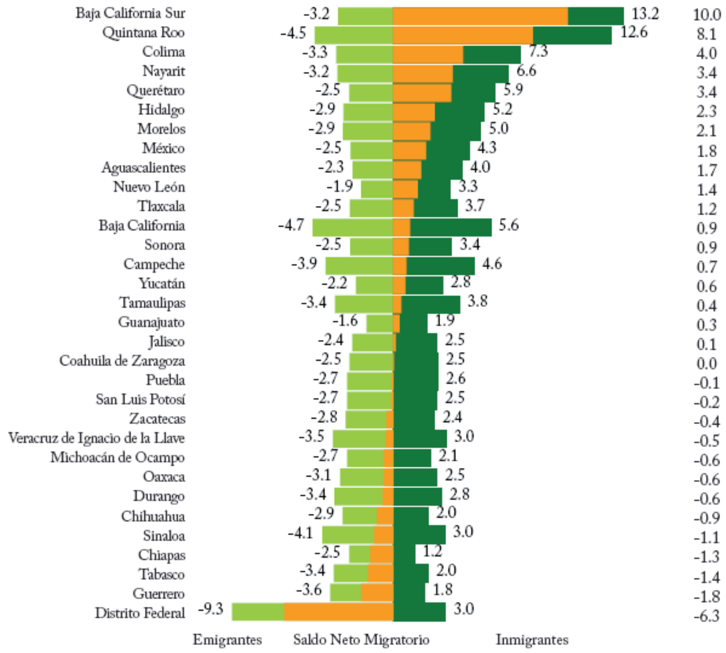
Description of Inputs

Our analysis of the determinants of migration is based upon Mexico's Population and Housing Census 2010 (the 'Census') that provides a demographic and socioeconomic description of a representative sample of the population of Mexico at the municipal level, and importantly the distribution of this sample within the country. Additionally, atmospheric and soil-type data were used to explore firstly the relationships between changes in population distribution and changes in climate and, secondly, the influences of climate change on agricultural activity which could then be linked to changes in population distribution.

The Census was divided into two sections by INEGI. The first section groups population characteristics (gender, age, fertility, internal migration, international migration, indigenous language, disability, education, socioeconomic characteristics, health, religion, etc) and the second section details housing characteristics (type of construction, size and use of space, utilities and sanitary facilities, fuel for cooking, holding and form of acquisition, goods and information technology and communication, among other variables of interest). The first section that also provides information related to internal and international migration forms a cornerstone of our analysis.

The Census reports that 3.3 million people over the age of 5 were registered as living in a different property in 2010 than 2005 (it should be noted that some people do not formally register their movement). During the same year, the three most-attractive states were Baja California Sur, Quintana Roo and Colima, with the least attractive being the Federal District, Guerrero and Tabasco, which lost 6.3 per cent, 1.8 per cent and 1.4 per cent of the population, respectively.

Figure 2: Percentage of Immigrants, Migrants and Net Migration by State, 2010.

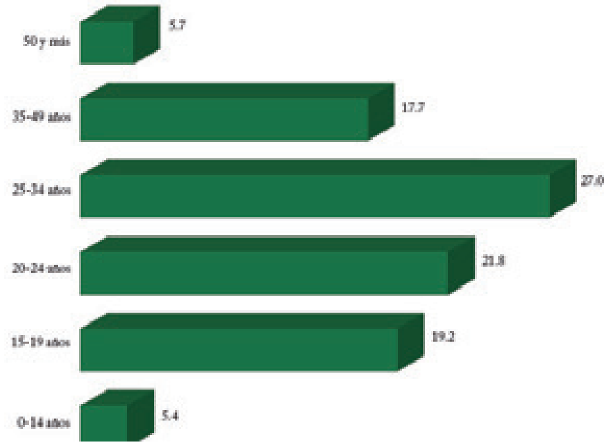


Source: INEGI, 'Preliminary Results of Mexico's Population and Housing Census', 2010.

In terms of international migration, the Census indicates that the bulk of international migrants (48.8 per cent) are young people of working age 20–34, while 20 per cent belong to a much younger age range, 15–19. Migration among those aged 50 and above only accounts for 5.7 per cent of the total. An additional feature of this phenomenon is that the five municipalities with the highest rate of outward migration – Leon (Guanajuato), Puebla (Puebla), Juarez (Chihuahua), Zapopan (Jalisco) and Morelia (Michoacán) – together account for 6 per cent of Mexico's international migrants.

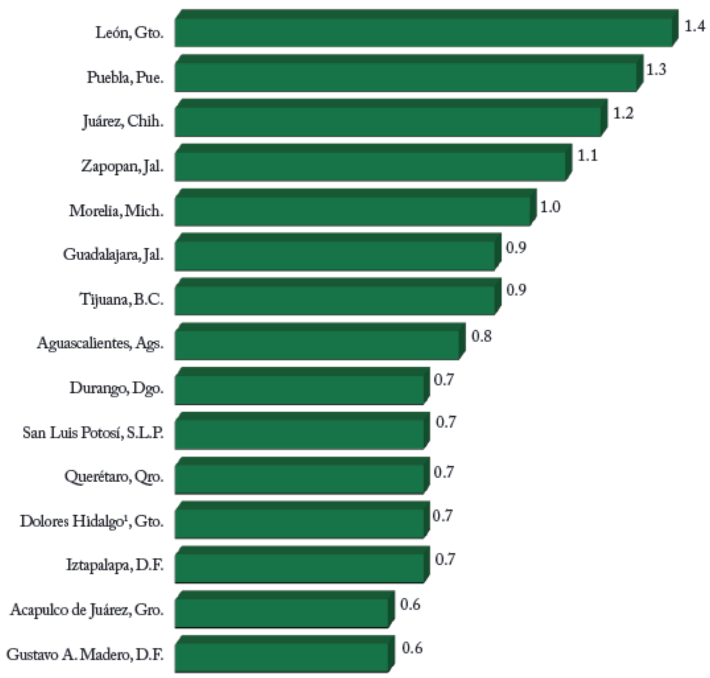
In addition to the data from the Census, this study used two environmental datasets: 1) atmospheric data (temperature and precipitation) at the municipal level, and 2) information on the dominant type of soil in each municipality of Mexico. These two sets of variables contribute directly to characterise the locations of origin of migrants. Temperature and precipitation reflect the prevailing climatic conditions across Mexico, whereas the dominant soil characteristics in each municipality allow us to consider the influence of climatic variables on each of these soil types and thus control for the influence of different soil productivities on the decision to migrate. The model seeks to estimate the size and direction of the influence of climate and soil variables on the decision of an individual to migrate.

Figure 3: Percentage Distribution of International Migrants by Age, 2010.



Source: INEGI, 'Preliminary Results of Mexico's Population and Housing Census, 2010'.

Figure 4: Percentage of International Migrants of Fifteen Major Municipalities from which Migration Originates, 2010.



Source: INEGI, 'Preliminary Results of Mexico's Population and Housing Census, 2010'.

Upon consideration of the variables used in the current model, it should be noted that the climate in any particular region in the world can be understood as the average climate condition that is observed over a certain period of time. In general, observations across a thirty-year period are used to determine the average climate of a region, which includes the average monthly values of atmospheric variables such as temperature and precipitation. In studies related to climate change, the period from 1961 to 1990 is commonly used (it is the only available data set with the level of resolution required) as the base period from which to calculate the climatic changes in each variable with respect to that period.[50]

Due to their importance, temperature and precipitation 'climatologies' are used in studies to assess the impact of climate change (see Appendix C). This information becomes very useful as it provides the basis for which variations in both precipitation and temperature associated with climate change can be quantified. After a region has been selected for its analysis, in this case the municipalities of Mexico, and with the base scenario in place, the next step in the development of climate-change scenarios is to choose the models that will be used in order to generate the information required for the climate variables used in this study.

Taking into account the IPCC Task Group on Scenarios for Climate and Impact Assessment (IPCC-TGICA), Mexican researchers have selected a number of models that represent the range of uncertainty, including the approximate range of possible increases in temperature as well as increases and reductions in precipitation. Thus, taking into account all the criteria of IPCC-TGICA[51] it is recommended to use these models: ECHAM5, HadGEM1, GFDL CM2.0 and 3.2-HIRES MIROC. Following these recommendations, this study uses HadGEM1 and 3.2-HIRES MIROC models; for a more detailed justification of these models and the scenarios used, see Appendix C. We note that the 3.2-HIRES MIROC model is the most advanced of the two for the modelling of terrestrial processes and has twice the spatial resolution of the atmospheric processes. 'Climatologies' of current and future average temperature and precipitation were generated using the base period 1961–90 (all at the municipal level). In the two models mentioned, projections up to 2030 were made using the only scenario that contains the necessary resolution of information, the A1B emissions scenario. This was carried out by the Climate Group and Solar Radiation Center for Atmospheric Sciences at UNAM (see Appendix C).

Information regarding the characteristics of different soil types in Mexico shows that there are at least fifteen types of soil, of which three are particularly relevant: Regosol, Litosol and Xerosoli.[52] A soil map from INEGI was used to determine the predominant type of soil in each municipality.[53] The information related to the types of soil in this database is in accordance with the Classification System of the Food and Agriculture Organisation (FAO).

Description of the Variables Used in the Econometric Model
Socio-demographic variables relevant to this study were generated from a random sample comprising 25 per cent of the available micro-data sample of the 2010 Census of Population and Housing. For the purpose of this study, only those individuals above 12 years old were considered, as INEGI defines this age range as the economically active population. Records with information gaps, such as the absence of data in the age variable, were omitted. As we mentioned above, the meteorological data on temperature and precipitation were provided by the Climate Group and Solar Radiation Centre for Atmospheric Sciences at UNAM.

Table 1 presents the descriptive statistics of key variables used in this analysis. The data are divided into three categories: individual characteristics, family

Table 1: Descriptive Statistics of Key Variables.

Variable	Mean	Std. Dev.	Min	Max
Individual Characteristics				
Gender (dummy, 1 = male)	0.486	0.5	0	1
Age	36.758	18.375	13	130
Household head (dummy)	0.332	0.471	0	1
Civil status household head (dummy, 1 = married)	0.565	0.496	0	1
Family Characteristics				
Mean household years of schooling	6.167	3.315	0	24
No. of members over 15 years old in the family	3.564	1.724	0	21
No. of rooms per house	2.095	1.022	1	12
Kitchen	0.895	0.487	0	9
Sanitary services	0.932	0.366	0	9
Access to piped water (dummy)	0.851	0.356	0	1
Drainage system (dummy)	0.777	0.416	0	1
Climate Characteristics				
Mean annual temperature (MIROC)	19.902	3.317	13.050	26.908
Total annual precipitation (MIROC)	1355.137	378.975	190.300	2147.500
Mean annual precipitation (MIROC)	112.928	31.581	15.858	178.958
Mean annual temperature (HadGEM1)	19.128	3.142	12.717	27.217
Total annual precipitation (HadGEM1)	1391.022	471.009	100.800	2458.000
Mean annual precipitation (HadGEM1)	115.919	39.251	8.400	204.833

Sources: 2010 Census of Population and Housing; meteorological data provided by UNAM.

characteristics (information obtained from the 2010 Census), and climate characteristics generated at the municipal level.

In the individual characteristics, it can be observed that gender does not present substantial differences as 49 per cent of the sample is male. The average age is close to 37 years old with a standard deviation of 18.4 years, but it should be remembered that only individuals above 12 years old were included. 33.2 per cent of respondents were found to be household heads and 56.5 per cent of them are married.

Looking at family characteristics, it can be noted that the average years of schooling of household members over 12 years old is six years. Conversely, access to education among Mexican households is very heterogeneous – while there are people who did not have access to education, there are also people with 24 years of schooling (i.e. who have completed higher education). It should also be noted that on average, 3.6 household members are above 15 years old. Despite this, the average number of bedrooms in each house is just two, 90 per cent have a kitchen and 93 per cent have access to sanitary services. Nevertheless, 15 per cent of households have no piped water available for domestic use and on average two in ten homes lack a drainage system.

Regarding the climate variables corresponding to the weather database and considering the data at the municipal level of the models used (MIROC and HadGEM1), the following analysis emerges. On the first model (MIROC), the average annual temperature is 19.9°C, while on the second model (HadGEMI)

Table 2: Demographic Characteristics of the 2010 Census Sample.

Variable	Migration Destination		
	No Migration	**Internal Migration**	**International Migration**
Individual Characteristics			
Gender (dummy, 1 = 100% male)	0.480	0.489	0.796
Age	37.033	32.434	27.467
Family Characteristics			
Mean household schooling (years)	6.137	7.669	5.538
No. of family members older than 15	3.557	3.148	4.512
No. of rooms per house	2.097	1.972	2.167
Access to health services	0.931	0.966	0.933
Access to piped water (dummy)	0.850	0.889	0.850
Drainage system (dummy)	0.775	0.868	0.758

is 19.1°C. Regarding the annual accumulated rainfall, the MIROC model indicates an average of 1355.1 mm/year while HadGEM1 presents 1391.0 mm/year for all the municipalities of Mexico. As it can be noted, these figures are not significantly different in their average value, whereas the scatter in the data for the model HadGEM1 is greater, as seen in its extreme values and standard deviation. The average annual precipitation is 112.9 mm/year with the MIROC model and a bit more with the HadGEM1 model, but as in the case of the previous variable, this second model has a higher standard deviation (39.3 mm/year).

Table 2 presents some of the socio-demographic characteristics of the census sample used in this study, grouped into three sub-populations:

- Individuals who live in their home (no migration)
- Individuals who have joined the national migratory flow (internal migration), defined as those who changed their residence from one state to another between 2005 and 2010
- Those who joined the international migratory flow during the same period.

(It is not possible to obtain information on households that moved completely, due to the nature of the available data. We can only measure the effect on temporary migration using census data. However, this phenomenon does not affect the results obtained.)

These data provide a fascinating insight into the demographics of the different groups of migrants, and several key observations stand out. Firstly, the average age of people who do not migrate is higher than those who migrate internally, which, in turn, is greater than those who migrate internationally. Secondly, a slight majority of non-migrants and internal migrants are women; in contrast, nearly 80 per cent of international migrants are men. Additionally, households with international migrants have fewer years of schooling compared with non-migrants and internal migrants, yet these households are made up more proportionally of working-age members, measured as the number above 15 years of age. Finally, indications of wealth and economic activity can be inferred through variables such as the number of household rooms, or the presence or absence of certain services.

Many such trends can be identified in these data and it is clear that the relationship between the different variables among different population groups is very complex. Therefore, simple statistical analysis does not provide clear and precise inferences of the influence of these variables on the decision to migrate. It is therefore essential to implement a more appropriate method for more precisely identifying the variables that influence the decision to migrate. In this case, we have used a multivariate

Table 3: One- and Two-Destination Logit and Multinomial Logit Models/ HadGEM1 (A1B).

Variable	Migration Destination		
	Total Migration	**Internal Migration**	**International Migration**
Mean annual temperature	-0.0434	0.0797	-0.3490
	(2.92)***	(4.53)***	(12.16) ***
Mean annual temperature (squared)	0.0007	-0.0018	0.0070
	(1.86)*	(3.99)***	(9.49) ***
Mean annual precipitation	0.0028	-0.0072	0.0337
	(6.22)***	(14.43)***	(32.5) ***
Mean annual precipitation (squared)	-7.94E-06	33.9E-06	-0.0001
	(3.94)***	(14.84)***	(30.06) ***
Gender (dummy, 1 = male)	0.4315	0.0310	1.4924
	(57.54)***	(3.49)***	(91.27) ***
Age	0.0373	0.0261	0.0970
	(31.01)***	(19.32)***	(33.75) ***
Age (squared)	-0.0008	-0.0005	-0.0019
	(48.03)***	(31.28)***	(44.15) ***
Mean household schooling (years)	0.0527	0.1038	-0.1259
	(43.26)***	(78.44) ***	(45.59) ***
No. of members older than 15	0.0553	-0.1430	0.2995
	(23.25)***	(41.52) ***	(93.38) ***
No. of rooms per house	-0.2774	-0.3519	0.2721
	(25.46)***	(29.49) ***	(11.73) ***
No. of rooms per house (squared)	0.0207	0.0361	-0.0664
	(11.25)***	(18.85) ***	(16.21) ***
Access to piped water (dummy)	0.0716	0.0303	0.1629
	(6.05)***	(2.03)**	(8.49) ***
Drainage system (dummy)	0.2396	0.3566	0.1504
	(22.01)***	(24.96) ***	(8.83) ***
Constant	-3.6920	-4.2510	-5.3371
	(25.01)***	(24.16) ***	(19.07) ***

* Significant at 10%; ** significant at 5%; *** significant at 1%. Z statistics are in parentheses.

Table 4: One- and Two-Destination, Logit and Multinomial Logit Models/ MIROC 3.2-HIRES (A1B).

Variable	Migration Destination		
	Total Migration	Internal Migration	International Migration
Mean annual temperature	0.0809	0.1468	-0.1155
	(5.21)***	(8.17***)	(3.59) ***
Mean annual temperature (squared)	-0.0025	-0.0037	0.0015
	(6.44)***	(8.26) ***	(1.84)*
Mean annual precipitation	-0.0020	-0.0020	0.0235
	(3.15) ***	(2.82)**	(16.62) ***
Mean annual precipitation (squared)	-1.53E-06	-21.6E-6	-0.00007
	(0.52)	(5.97) ***	(11.83) ***
Gender (dummy, 1 = male)	0.4293	0.0277	1.4912
	(57.25) ***	(3.12) ***	(91.21) ***
Age	0.0368	0.0252	0.0973
	(30.57) ***	(18.66) ***	(33.85) ***
Age squared	-0.0008	-0.0005	-0.0019
	(47.71) ***	(30.72) ***	(44.22) ***
Mean household schooling (years)	0.0493	0.0989	-0.1245
	(40.16) ***	(74.09) ***	(44.95) ***
Number of members older than 15	0.0595	-0.1363	0.2980
	(25.05) ***	(39.6) ***	(93.17) ***
No. of rooms per house	-0.2870	-0.3670	0.2807
	(26.58) ***	(31.07) ***	(12.12) ***
No. of rooms per house (squared)	0.0220	0.0378	-0.0667
	(12.12) ***	(20.14) ***	(16.29) ***
Access to piped water (dummy)	0.0440	-0.0286	0.1942
	(3.72) ***	(1.91)*	(10.12) ***
Drainage system (dummy)	0.2285	0.3434	0.1350
	(21.03) ***	(24.09) ***	(7.93) ***
Constant	-4.3552	-4.5318	-7.5170
	(27.48) ***	(24.45) ***	(23.7) ***

*Significant at 10%; **significant at 5%; ***significant at 1%. Z statistics are in parentheses.

regression method, multinomial logit, which controls these correlations in order to obtain accurate estimates of the effects of different characteristics of individuals, families and their migration.

Results of the Multinominal Logit Model

This section presents the results of the MLM used to measure the impact of climate variables on the decision to migrate in Mexico. Firstly, migration decisions are evaluated using a simple logit model with two possible outcomes: non-migrant and migrant (both domestic and international). Secondly, the results of the MLM are presented in terms of the three types of immigration: no migration, internal migration and international migration. (For more detailed explanation of the MLM, see Appendix B.)

The coefficients for the key variables are shown in Tables 3 and 4. Table 3 shows the climate data output from the HadGEM1 model, while Table 4 shows climate data from the MIROC model. The 'Total Migration' column shows the coefficients for total migration using the logit model, while the 'Internal' and 'International' columns are the coefficients associated with the MLM within the three migration regimes.

Each table presents the results of different variables that have been grouped into two sets: climate variables (average temperature and precipitation, along with their quadratic expressions) and socio-demographic variables (individual, family and housing). The coefficients and significance levels in Tables 3 and 4 show that in all cases, both sets of variables play an important role in the decision to migrate. However, in some cases, the effects of these variables differ among various types of migration. A more detailed description for each of the cases is presented below.

Total Migration

Total migration includes a heterogeneous mix of internal and international migration. The aim of this estimate is to find the key variables in the decision that individuals make when changing residence, regardless of their final destination. The 'Total Migration' data in Tables 3 and 4 reveal that, despite this heterogeneity, almost all of the socio-demographic and climate variables are important in explaining the movement of people.

The following key findings are observed:

- Men show a greater propensity to migrate than women
- The age variable behaves as expected in relation to previous studies on the determinants of migration – the probability of the individual to migrate increases with age, but at a decreasing rate, which reflects the selectivity of migration in the working-age population
- The probability of the individual to migrate significantly increases with

the average years of schooling of household members, the number of household members older than fifteen years old, and the access to basic services such as piped water and drainage systems
- Higher temperatures have a positive effect on the decision to migrate: in those places where the temperature is extremely high, there is statistical evidence that an individual may have a greater incentive to migrate.

Internal Migration

The coefficients in Tables 3 and 4 highlight that the impact of key variables, and, in particular, climate variables, is not uniform among migration destinations; an indication of the existence of enormous variety of climates and microclimates throughout Mexico.

The results of the MLM, which explores the differences in the choices through the migration destination, are shown in the 'Internal' and 'International' columns in Tables 3 and 4. These results are consistent between HadGEM1 and MIROC models. The following observations can be noted:

- As in the case of total migration, men are more likely to migrate internally
- Migrants are of a young and economically productive age
- Higher levels of average schooling in a family have a significant positive effect on internal migration
- The proxy variable used to identify the different levels of wealth (number of rooms in the house) shows that individuals with higher levels of wealth are less likely to migrate internally
- Increasing average temperature has a significant positive impact on the decision to migrate
- Increasing average precipitation has a negative impact.

International Migration

Finally, the results for the MLM demonstrate the following trends:

- International migrants are significantly more likely to be men of working age
- There is a noticeable difference in the association between education levels and migration for both types of migration (internal and international)
- Unlike for national migration, higher levels of average schooling in a family have a significant negative effect on international migration
- This different behaviour between migratory destinations also occurs for number of working-age household members: while this variable has a negative effect on domestic migration, the impact is positive in the case of international migration

- The propensity to migrate internationally increases with the household wealth. The proxy variable of wealth has a positive and significant effect on international migration.

Regarding the effects of the climate variables, the direction (reported as the sign of the coefficient) and the statistical significance levels of these variables are mostly the same for each model, as can be seen in a comparison of the coefficients in Tables 3 and 4. This suggests that the temperature and precipitation variables associated with international migration are related by more than chance, regardless of the type of climate data used. It is observed that despite using different data sets that respond to different climate models, the results associated with the decisions of national and international migration are consistent: we find good evidence to suggest that studies seeking to determine the variables that influence the decision to migrate should consider contextual variables in the environment or climate.

Marginal Effects

Using the coefficients in Tables 3 and 4, and holding all independent variables constant at their average value, the marginal effects of each variable can be studied in turn, as presented in Table 5 (HadGEM1) and Table 6 (MIROC). Marginal effects – a powerful representation of the direct impact of each dependent variable on the decision to migrate – are expressed in Tables 5 and 6 as probabilities. As can be seen by comparing the results in each table, the outcomes obtained are robust across the different climate models used. In practice, we take each variable in turn, increment it by one unit and observe the change in influence on the probability to migrate.

For example, using the model HadGEM1 it can be seen that increasing the mean annual temperature by 1°C results in the probability of joining an internal migration flow increasing by 0.0014. The effect is negative for international migration and equal to a change of 0.0006. If we consider the influence of mean annual temperature on any type of migration, the net effect would be positive and equal to a 0.0008 increase in the probability of migration. These small numbers may seem negligible, but the importance lies within the significance levels and the sign of these coefficients proving that the relationship between climate variables (temperature and precipitation) are non-zero and statistically significant.

To illustrate the real-world meaning of these values, we discuss a hypothetical, practical example. IPCC scenario A1FI predicts an increase in global temperatures of between 2.4 to 6.4°C by 2100[54] and the INEGI reports that in 2010 the economically active population in Mexico is near to 50 million people. Using these data, our model predicts that internal migration would increase between 176,400 and 470,400 people[55] as a direct result of increasing temperatures alone by the end of the century. This range assumes

Table 5: Marginal Effects on a Two-Destination, Multinomial Logit Model/ HadGEM1 (A1B).

Variable	Migration Destination	
	Internal Migration	International Migration
Mean annual temperature	0.00147	-0.00063
Mean annual precipitation	-0.00014	0.00006
Gender (dummy, 1 = male)	0.00046	0.00695
Age	0.00048	0.00018
Mean household schooling (years)	0.00202	-0.00053
Number of members older than 15 years	-0.00279	0.00126
Number of rooms per house	-0.00541	0.00026
Access to piped water (dummy)	0.00057	0.00064
Drainage system (dummy)	0.00629	0.00058

Source: Authors' calculations, based on the coefficients in Table 3 and the mean values of each independent variable.

that the temperature increase remains constant, and even neglects the fact that the population of Mexico is increasing, and is also independent of all other contributions from various environmental, social or economic factors. Thus, a relationship between climate change and migration is evidenced and shown to be statistically significant. It should be noted that migration is a multi-causal phenomenon and the single climate variable, temperature, is only one component of total internal migration. Equally important is the comparison of the influence of temperature with the influence of

Table 6: Marginal Effects on the Two-Destinations, Multinomial Logit Model\MIROC 3.2-HIRES (A1B).

Variable	Migration Destination	
	Internal Migration	International Migration
Mean annual temperature	0.01052	-0.09552
Mean annual precipitation	-0.00016	0.01985
Gender (dummy, 1 = male)	0.00039	0.00696
Age	0.00182	0.07933
Mean household schooling (years)	0.00190	-0.00053
Number of members over 15 years	-0.00263	0.00125
Number of rooms per house	-0.02198	0.12501
Access to piped water (dummy)	-0.00057	0.00076
Drainage system (dummy)	0.00600	0.00052

Source: Authors' calculations, based on the coefficients in Table 4 and the mean values of each independent variable.

demographic variables such as gender, which have been demonstrated to have a significant influence on the decision to migrate.[56] As shown in Table 5, being male increases the probability of national and international migration by 0.0004 and 0.00695 respectively. Therefore, according to our analysis, an increased temperature has a greater influence on the decision to migrate internally than gender.

The impact of an additional year of schooling is positive for domestic migration and negative internationally. We also note that international migrants come from households with higher wealth, as indicated by the estimated marginal effect for the variable of number of rooms in the home; the effect is negative for domestic migration, indicating that destinations within the country can be reached at lower cost, and thus more accessible to domestic destinations for individuals with less wealth. Importantly, the identified impacts observed for the HadGEM1 model in Table 5 are maintained with the MIROC model, whose marginal effects are shown in Table 6.

Regional Effects

In order to explore in more detail the effects we found to be statistically significant at the national level regarding the influence climatic variables have on migration decisions, we divided Mexico into different regions.

There is a regional heterogeneity in Mexico in terms of access to natural resources, economic capabilities, cultural diversity and infrastructure. The combination of these factors has different effects on the migratory flow that Mexico experiences. Considering previous migration studies, we adopt a typical form of regional classification based on the flow of dollars from the United States in remittances. This has the advantage that it allows us to quantify migration flows and it also gives a relative distribution of remittances sent by migrants. In this regard,[57] with reference to the National Survey on Migration Survey in the Northern Border of Mexico (EMIF),[58] we group the country into four regions:

- The Traditional Region: Aguascalientes, Colima, Durango, Guanajuato, Jalisco, Michoacan, Nayarit, San Luis Potosi and Zacatecas
- The Northern Region: Baja California, Baja California Sur, Coahuila, Chihuahua, Nuevo Leon, Sinaloa, Sonora and Tamaulipas
- The Central Region: the Federal District, Hidalgo, Mexico, Morelos, Puebla, Queretaro and Tlaxcala
- The South-Southeast Region: Campeche, Chiapas, Guerrero, Oaxaca, Quintana Roo, Tabasco, Veracruz and Yucatan.

Tables 7 and 8 present the coefficients for each MLM developed for the four regions. The results with the MIROC model appear in Table 7, while Table 8 presents the results with the HadGEM1 model. According to the

Table 7: Two-Destination, Multinomial Logit Model/MIROC 3.2-HIRES (A1B).

Variable	Migration Destination by Region							
		Internal Migration				International Migration		
	Traditional	North	Centre	South	Traditional	North	Centre	South
Mean annual Temperature	-0.101	-0.355	8.267	0.124	0.341	-0.111	1.775	0.004
	(1.18)	(3.67)***	(21.72)***	(0.96)	(5.6)***	(3.0)***	(8.5)***	(0.05)
Mean annual temperature (squared)	0.001	0.008	-0.230	-0.005	-0.007	0.005	-0.046	-0.002
	(0.55)	(3.02)***	(21.8)***	(1.62)	(4.38)***	(4.84)***	(8.0)***	(1.15)
Mean annual precipitation	0.056	-0.028	-0.019	0.020	-0.058	-0.032	-0.266	-0.008
	(8.69)***	(3.49)***	(0.55)	(8.27)***	(13.13)***	(9.93)***	(12.62)***	(4.79)***
Mean annual precipitation (squared)	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
	(8.71)***	(3.91)***	(0.4)	(9.03)***	(10.64)***	(6.48)***	(11.18)***	(1.23)
Gender (dummy, 1 = male)	1.458	0.766	1.589	1.615	0.029	-0.024	-0.028	0.120
	(50.56)***	(13.29)***	(46.14)***	(59.63)***	(1.39)	(1.01)	(1.84)*	(7.56)***
Age	0.057	0.084	0.148	0.164	0.023	0.010	0.013	0.046
	(13.76)***	(7.44)***	(21.57)***	(28.55)***	(7.48)***	(2.81)***	(5.76)***	(18.72)***
Age (squared)	-0.001	-0.002	-0.003	-0.003	0.000	0.000	0.000	-0.001
	(19.78)***	(9.7)***	(25.59)***	(33.88)***	(12.46)***	(9.27)***	(12.98)***	(24.44)***
Mean household schooling (years)	-0.089	-0.001	-0.110	-0.165	0.103	0.063	0.093	0.102
	(18.45)***	(0.07)	(19.35)***	(34.18)***	(33.55)***	(17.31)***	(41.31)***	(41.32)***
Number of members older than 15 years	0.327	0.454	0.287	0.280	-0.123	0.001	-0.182	-0.152
	(54.74)***	(31.81)***	(42.86)***	(55.88)***	(15.18)***	(0.1)	(30.54)***	(25.69)***
Number of rooms per house	-0.014	-0.050	0.133	0.420	-0.367	-0.626	-0.322	-0.273
	(0.33)	(0.53)	(2.9)***	(11.01)***	(12.85)***	(19.66)***	(16.51)***	(12.98)***
Number of rooms per house (squared)	-0.039	-0.029	-0.048	-0.073	0.036	0.057	0.034	0.032
	(5.74)***	(1.75)*	(6.05)***	(10.39)***	(8.1)***	(10.9)***	(11.13)***	(9.42)***
Access to piped water (dummy)	0.191	0.589	-0.015	0.237	0.084	-0.264	-0.191	0.074
	(4.26)***	(4.02)***	(0.35)	(9.36)***	(1.89)*	(5.14)***	(6.94)***	(3.49)***
Drainage system (dummy)	0.296	0.436	0.153	0.091	0.303	0.318	0.321	0.330
	(7.75)***	(4.54)***	(3.8)***	(3.88)***	(7.67)***	(7.46)***	(10.56)***	(16.3)***
Constant	-8.292	-4.360	-80.660	-10.556	-4.017	-1.935	-2.260	-2.261
	(9.5)	(4.56)***	(28.51)	(7.9)***	(6.26)***	(4.95)***	(1.5)	(2.42)**

*Significant at 10%; **significant at 5%; ***significant at 1%. Z statistics are in parentheses.

Table 8: Two-Destination, Multinomial Logit Model/HadGEM1 (A1B).

Variable	Migration Destination by Region							
	Internal Migration				International Migration			
	Traditional	North	Centre	South	Traditional	North	Centre	South
Mean annual temperature	-0.222	-0.255	0.9099	-1.032	-0.434	-0.694	0.1708	-0.465
	(3.1)***	(1.84)*	(18.34)***	(8.21)***	(7.58)***	(14.66)***	(6.23)***	(5.64)***
Mean annual temperature (squared)	0.004	0.004	-0.273	0.023	0.015	0.024	-0.053	0.010
	(2.18)**	(1.09)	(18.53)***	(7.74)***	(9.75)***	(18.07)***	(6.43)***	(5.22)***
Mean annual precipitation	0.034	-0.010	-0.075	0.035	-0.073	-0.027	0.033	0.008
	(7.1)***	(2.52)**	(10.97)***	(12.58)***	(18.75)***	(17.32)***	(6.91)***	(5.05)***
Mean annual precipitation (squared)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(6.38)***	(4.59)***	(9.64)***	(11.43)***	(17.91)***	(12.68)***	(7.97)***	(6.64)***
Gender (dummy, 1 = male)	1.461	0.766	1.582	1.614	0.027	-0.025	-0.027	0.121
	(50.65)***	(13.28)***	(45.96)***	(59.6)***	(1.29)	(1.06)	(1.8)*	(7.61)***
Age	0.057	0.083	0.146	0.165	0.023	0.010	0.013	0.046
	(13.74)***	(7.39)***	(21.35)***	(28.62)***	(7.53)***	(2.76)***	(6.04)***	(18.86)***
Age (squared)	-0.001	-0.002	-0.003	-0.003	0.000	0.000	0.000	-0.001
	(19.74)***	(9.68)***	(25.44)***	(33.9)***	(12.54)***	(9.19)***	(13.21)***	(24.34)***
Mean household schooling (years)	-0.088	-0.005	-0.119	-0.161	0.104	0.065	0.098	0.108
	(18.21)***	(0.47)	(21.21)***	(33.89)***	(33.58)***	(17.82)***	(43.55)***	(44.21)***
Number of members older than 15 years	0.325	0.456	0.289	0.279	-0.120	0.003	-0.185	-0.155
	(54.43)***	(31.87)***	(43.34)***	(55.79)***	(14.75)***	(0.32)	(31.02)***	(26.29)***
Number of rooms per house	-0.007	-0.042	0.183	0.435	-0.380	-0.625	-0.320	-0.256
	(0.17)	(0.45)	(3.96)***	(11.39)***	(13.32)***	(19.54)***	(16.39)***	(12.04)***
Number of rooms per house (squared)	-0.040	-0.030	-0.057	-0.075	0.038	0.057	0.034	0.030
	(5.91)***	(1.83)*	(7.05)***	(10.61)***	(8.4)***	(10.74)***	(11.12)***	(8.58)***
Access to piped water (dummy)	0.174	0.487	-0.010	0.231	0.063	-0.256	-0.180	0.096
	(3.89)***	(3.36)***	(0.23)	(9.1)***	(1.4)	(4.99)***	(6.56)***	(4.53)***
Drainage system (dummy)	0.301	0.367	0.142	0.075	0.207	0.277	0.332	0.334
	(7.94)***	(3.88)***	(3.51)***	(3.19)***	(5.26)***	(6.5)***	(10.94)***	(16.44)***
Constant	-5.752	-5.399	-77.113	0.092	2.799	2.075	-18.806	0.601
	(7.92)***	(4.38)***	(18.79)***	(0.07)	(4.58)***	(4.49)***	(8.36)***	(0.72)

*Significant at 10%; **significant at 5%; ***significant at 1%. Z statistics are in parentheses.

Table 9: Marginal Effects on Two-Destinations, Multinomial Logit Models. MIROC 3.2-HIRES (A1B)

Variable	Migration Destination by Region							
	Internal Migration				International Migration			
	Traditional	North	Centre	South	Traditional	North	Centre	South
Mean annual temperature	-0.1887	-0.6476	0.1490	0.2189	0.0052	-0.0016	0.0267	-0.00001
Mean annual precipitation	0.1066	-0.0519	-0.0359	0.0382	-0.00091	-0.0005	-0.0042	-0.00012
Gender (dummy, 1 = male)	0.0137	0.0020	0.0052	0.0043	0.00025	-0.0005	-0.0008	0.0017
Age	0.1053	0.1536	0.2717	0.3007	0.0003	0.0001	0.0002	0.0007
Mean household schooling (years)	-0.0007	-0.000005	-0.0003	-0.0003	0.0017	0.0014	0.0024	0.0015
Number of members older than 15 years	0.0028	0.0012	0.0008	0.0006	-0.0021	-0.000006	-0.0047	-0.0022
Number of rooms per house	-0.1755	-0.2056	0.0699	0.5212	-0.0047	-0.0081	-0.0040	-0.0033
Access to piped water (dummy)	0.0015	0.0012	-0.000026	0.00051	0.0013	-0.0064	-0.0053	0.00104
Drainage system (dummy)	0.0022	0.00096	0.00039	0.0002	0.0045	0.0061	0.0075	0.0045

Source: Authors' calculations, based on the coefficients in Table 7 and the mean values of each independent variable.

MIROC climate model data, the average annual temperature has a statistical significance for internal migration; negatively in the northern region and positively in the central region. In the case of international migration, this variable is positive and statistically significant in the central and traditional regions, while also negative for the northern region.

Annual average rainfall has a positive impact on the probability of internal migrants in the south-southeast and traditional regions, and negative in the northern region. For the central region, the impact on internal migration is not statistically different from zero. Regarding international migration, the impact of annual average precipitation is negative and statistically significant for all regions. It is also possible to note that in general, the results described above are maintained for the HadGEM1 model, as shown in the coefficients in Table 8.

Considering the marginal effects at the regional level, it is possible to corroborate what has been described above. For example, in Table 9 for the MIROC model, the impact of a unit increase in mean annual temperature would imply different effects on internal migration for different regions – namely a positive impact equal to a probability of 0.149 in the central region, and 0.2189 in the south. In the northern and traditional regions, the impact

Table 10: Marginal Effects on Two-Destination, Multinomial Logit Models/HadGEM1 (A1B).

Variable	Migration Destination by Region							
	Internal Migration				International Migration			
	Traditional	North	Centre	South	Traditional	North	Centre	South
Mean annual temperature	0.0427	0.0256	0.4752	-0.5457	0.4459	0.4796	0.3745	-0.1040
Mean annual precipitation	-0.0067	0.0010	-0.4103	0.1932	0.7913	0.2016	0.0757	0.0193
Gender (dummy, 1 = male)	0.0137	0.0020	0.0054	0.0043	0.00021	-0.00057	-0.00085	0.0017
Age	-0.0110	-0.0083	0.7777	0.8751	-0.2436	-0.0698	0.0295	0.1050
Mean household schooling (years)	-0.00076	-0.00002	-0.00036	-0.00038	0.0017	0.0014	0.0026	0.0016
Number of members older than 15 years	0.0028	0.0012	0.00088	0.00065	-0.0020	0.00004	-0.0048	-0.0023
Number of rooms per house	0.0176	0.0107	3.8459	15.7400	3.3547	3.7943	-0.5901	-0.4582
Access to piped water (dummy)	0.0014	0.0010	-0.00001	0.00050	0.0010	-0.0061	-0.0051	0.0014
Drainage system (dummy)	0.0023	0.00081	0.00038	0.00016	0.0032	0.0054	0.0077	0.0047

Source: Authors' calculations based on the coefficients in Table 8 and the mean values of each independent variable.

has a negative direction and a probability of 0.6476 and 0.1887, respectively. As seen in Table 9, the impact on international migration is distinct: positive in the traditional and central regions (probabilities of 0.005 and 0.0026), and negative in the northern and south-southeast (probabilities of 0.0016 and 0.00001).

Also in Table 9, we see that a unit increase in average annual precipitation has a negative impact on internal migration in the northern and central regions, with a probability of 0.0519 and 0.0359 respectively, and a positive impact on the traditional and southern regions, with probabilities of 0.1066 and 0.0382.

Table 10 shows the marginal effects for the HadGEM1 model data: in several cases, they are different in magnitude and sign to the MIROC model, indicating how sensitive these results are to different climatological data. This leads us to suggest that, while there are limitations to this analysis, it is extremely important to generate climate data at higher levels of resolution to obtain conclusive results. Despite this and not forgetting that the marginal effects are obtained through the mean values of the variables, it may indicate that in this empirical study, we have found evidence to suggest that climate variables are statistically significant determinants in the decision to migrate.

Summary

Mexico is undergoing notable changes in climate in the midst of an array of hydrological events such as floods, droughts and hurricanes – the intensity and frequency of which are a growing trend. Some states and cities are certainly at more risk than others, but this is a national problem that must be addressed and tackled at the governmental level. This is underlined by the wide-reaching impact of climate change that affects many industrial sectors, from agriculture to energy, and also the health and the movement of people within and across borders.

In the first part of this section, Mexico's exposure to hydrological events, exacerbated by changes in climate, was demonstrated through previously published case studies. Broadly, the impact of climate change on these events can be described by two basic environmental parameters, temperature and precipitation patterns. Despite this apparent simplicity, the decision to migrate is multi-causal, and isolating the effects of climate change on this decision from the effects of economic, social or political issues requires a more complex approach. It is also important to recognise that research and assessments are scarce and more knowledge is needed in order to understand the relation between climate change and the extreme events and the existing and potential effects vulnerable people and regions could experience.

In the second part of this section, we attempt to address some of these challenges by using high-resolution atmospheric and demographic data to establish that changes in climate (temperature and precipitation) are statistically significant determinants in the decision to migrate, both internally and internationally in Mexico. It is essential to note that these econometric results should be considered as a first approximation of the potential effects that variations in climate (climate change) could have on migration. Obviously, it will be necessary to undertake comprehensive and multidisciplinary studies in order to reach conclusive results that are outside the scope of this investigation, but undoubtedly will be developed at a later stage.

Final Considerations

It is important to emphasise that the quantitative results of this research have to be seen as a first step in identifying the complex relationship between the possible effects of climate change, the various production activities – mainly in rural areas – and migration decisions in Mexico. In this quantitative analysis, the climate variables are generated from the two climate models, HadGEM1 and MIROC, in the base period 1960–91. We use this range as it is the most up to date, complete and publically available dataset.

By using data from the 2010 Census of Population and Housing, climate variables and soil characteristics at the municipal level, the econometric results of this research show that the climatic variables (temperature and precipitation) are statistically significant determinants of the decision to migrate in Mexico. However, it should be noted that people may not formally register their internal movements, and as such this movement may be missed by the census.

Another limitation of this model is that it is difficult to predict absolute numbers of migrants with confidence, as any estimation is reliant on the probability holding true, which may not be the case. However, the major innovation of the model is the level of significance and the non-zero probability that demonstrates the statistical significance of each variable in the MLM and concludes a relationship between the climate variables, temperature and precipitation, and the decision to migrate.

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III. Resource Competition and Security in Mexico

While the previous section suggests a statistically significant link between climate change and migratory patterns in Mexico, it must be remembered that the analysis is incapable of predicting absolute numbers of migrants as it only considers changes in probabilities. In this section, we explore practical examples of this linkage and their impact on Mexico, both past and future. Specifically, the focus is upon the impact of climate change on key resources such as water, food and energy, and the interconnections with migratory dynamics and the security landscape of Mexico.

Demand from emerging markets is currently raising the price of resources such as water, food and energy: this looks set to continue with up to 3 billion people potentially soon to join the global middle class.[1] This pressure, if sustained, could lead to global, national and even local competition for resources that will be compounded by environmental changes lowering productivity growth in agro-industrial sectors and severely affecting the availability of water. One of the major implications for the wellbeing of humans of extreme-weather events and gradual changes the climate is related to the availability and distribution of resources such as water, food, and energy, and the associated impact on infrastructure, forestry, tourism and health issues (such as the incidence of various vector-borne diseases).[2] Climate change alters the distribution of resources within a country and CIM heightens these problems, as perceptions of who is at a relative advantage and disadvantage will increase people's desire to move.

The combination of a decrease in precipitation, with maintenance of existing waste and contamination levels, will most likely decrease the availability of clean-water supply, leading to a decrease in the economic activity of the agricultural and industrial sectors, in turn leading to higher unemployment and a decrease in food supply. This likewise will be detrimental to the health of individuals who may opt to relocate or migrate to less-stressed areas. With a growing middle class, further urbanisation of mid- and mega-sized cities in Mexico and continuing changes in climate, it is important to understand the resource nexus[3] and assess the impact of poor practices in their production, management and use across all levels of society and between sectors, especially in urban areas – as well as the impact they could have on the decision to migrate and the related security issues.

Water Security

One of the major implications of extreme weather events and gradual changes in the climate is related to the availability and distribution of resources. The most critical for Mexico is water. This is not just a Mexican problem: the IPCC estimates that the reduced availability and increased consumption will create water stress for hundreds of millions of people globally.[4] It has been estimated that water consumption is increasing at twice the rate of global population growth and that 1.8 billion people will live in areas affected by absolute water scarcity in little over a decade.[5] In Latin America, the agricultural sectors and food industry consume water in volumes two-to-three-times higher than current US and Chinese levels. There is therefore significant scope for improvement of water efficiency or water supply infrastructure, particularly as the demand for water in Latin America is expected to exceed supply by more than 60 per cent by 2025.[6]

For Mexico, water availability and management issues already represent serious challenges for the government, due to unpredictable variations in temperature and rainfall, a lack of suitable water infrastructure in places, as well as substantial water contamination. The Mexican government has described the issue as ‘a strategic matter of national security’.[7]

More than 79 per cent of the Mexican population is located in urban areas (predicted to rise to 85 per cent by 2025[8]) with 45 per cent concentrated in only twenty-three cities in the north and centre of the country, an area with 32 per cent water availability. This area collectively produces 85 per cent of Mexico’s GDP. Approximately 49 per cent of urban population resides in only eight cities of the southeastern part of the country – a region that has 69 per cent water availability, 23 per cent of the population and produces 15 per cent of GDP. [9] In 2007, the amount of natural water per inhabitant in the Frontera Sur region was 169.7 times higher than in the Valle de Mexico region.[10] These discrepancies will most likely be exacerbated by more frequent and intense droughts, which will lead to competition between users and affect quality of life,[11] forcing residents to move to other regions or into urban areas in search of water. This will add further pressure on cities that already have deficient water supply – such as the Mexico City, which can barely meet the water demand of its existing residents. In this case, people are moving to the metropolitan area because they can have their needs met, despite the obstacles facing the city’s water management. This is forcing the government of Mexico City to search for other water sources, or even to promote water harvesting in the peri-urban interface or within the city itself.

Citizens in informal settlements in peripheral areas (the District of Xochimilco[12] and District of Tláhuac[13]), and areas in transition from rural to urban, have little or no access to public water supplies and are forced to pay high prices for bottled water through informal means, such as purchasing from private operators, wells or clandestine connections.[14] The latter could be a potential opportunity for criminal organisations to exploit vulnerable populations by controlling certain water supplies and holding them to ransom. Informal settlements are commonly inhabited by migrants pushed to the peripheries of the city and the very poor displaced from city centres.[15] Increased levels of CIM could lead to an increase in the number of informal or illegal settlements, as people move from rural to urban areas in search of work. Flood vulnerability in the peri-urban interface has also been predicted to increase due to a lack of governance, weak institutional arrangements and policy.[16]

In the north and the northwest, a decrease in rainfall between 10 and 15 per cent is expected. This could lead to more frequent and severe droughts and an approximate 20 per cent reduction in runoff in certain regions by the end of the twenty-first century.[17] Central Mexico, an area with a growing population, is moving in this direction and has already been classified as approaching a state of physical water scarcity:[18] 'Runoff in the region will likely decline by at least 5 per cent and possibly up to 50 per cent, with declines getting progressively worse in the semi-arid and arid north'.[19] A study analysing precipitation in nineteen climate models revealed that between 2021 and 2040, the north of Mexico and southern US will begin to suffer permanent droughts,[20] with major consequences for water availability, regional development, trans-boundary relations and migration. The latter may have significant effects on CIM in the light of the econometric results listed in Table 9, indicating that the reduction in rainfall could mean a bigger boost in migration to the northern and central regions of Mexico.

In Mexico, 64 per cent of the water consumed comes from surface water and is mostly used for agriculture, whereas 36 per cent comes from groundwater and is mostly used for domestic and industrial use. From the total extracted water in Mexico, 77 per cent is destined for agricultural activities, 14 per cent to public supply and 9 per cent to industry, agro-industry, services, business and thermal electrical power.[21] The demand for water has increased due to economic growth in areas where aquifers have low water levels. According to the INEGI, 104 of the 653 aquifers in Mexico are currently overexploited.[22]

It is of great importance to carefully consider rationing the use of water in order to avoid shortages hampering economic and social development. Water reserves are currently falling by 6 km^3 per year.[23] For example, the northern states that consume the largest volumes of water are Baja California Sur, Chihuahua and Coahuila. In terms of migration, this is particularly interesting; as these states consume the most water, we may expect that increasing stress upon available water could potentially drive population away from this region. In support of this, the outputs of the MLM presented in Tables 7 and 9 show us that if the annual mean precipitation were to increase (alleviating water stress) then migration from this northern region would decrease. It is also worth noting that Baja California, with the lowest population (637,065),[24] is among the states that consume the largest amount of water, mainly designated for agricultural production.

There is significantly less stress on water availability in the southern region (compared to the north). An increase in precipitation does not have the same alleviating effect as in the north, corroborating the results of Tables 8 and 10, in which migration is shown to be likely to increase rather than decrease. This could be for a number of reasons; though it is beyond the scope of our analysis to isolate one with confidence, however, the increased likelyhood of flooding could be one reason.

Water Quality

Floods and droughts also reduce the quality of water, and exacerbate many forms of water pollution.[25] Currently, the lack of available water in both quantity and quality represents one of the biggest problems for development in Mexico.[26] According to the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation 2012, between 1995 and 2010, 24 per cent more of the Mexican population gained access to drinking water sources, with coverage increasing 85 to 96 per cent. Additionally, 21 per cent more Mexicans gained access to sanitation facilities, rising to 85 per cent coverage. CONAGUA estimates that 86 per cent of the population has access to drinkable water and 83 per cent has access to sewerage. However – according to data from 2007 – this means that in absolute numbers, there were 10.8 million Mexicans without direct access to drinking water and 14.5 million without adequate sewerage.[27]

Mexico has improved general access to drinking water, but there is still more to do on improving access to safe, high-quality drinking water. Piping water to a village tap counts as 'improving' the supply – even if the tap brings bacteria-laden water untreated straight from a river. Worryingly, Mexico ranks 106th out of 122 countries in terms of the quality of its drinking water.[28] Mexico is also the second-largest consumer of bottled water in the world, after the US. The central region of the country (Valle de México) has particularly bad water quality, with other areas of concern being Pánuco, Lerma, Balsas, San Juan, Coatzacoalcos, Blanco, Papaloapan, Conchos, Coahuayana, Culiacán, Fuerte, Yaqui and Mayo y Bajo Bravo.[29]

Every year, water contamination affects food resources and spreads disease.[30] Shortages and poor quality of water lead to increases of hepatitis A, diarrhoea and cholera. Water shortages can disrupt crop-growing and result in undernourishment, which increases susceptibility to infection or encourages large-scale displacement. This can in turn put new pressure on sanitation and water supply in communities hosting migrants, and thus affect the health of both hosts and migrants.[31]

Rising sea levels are also causing salt intrusion into aquifers of coastal water basins and wells. In coastal settlements of the state of Tabasco, the Sánchez-Magallanes coast line retreated by 87 metres between 1985 and 2000 and in

Playa el Limon the retreat over the same period was 262 m.[32] In the context of climate change this phenomenon becomes increasingly significant, and will continue to jeopardise water extraction, consumption and security in coastal states of Mexico.

Water Competition

Water is a finite resource: as droughts lengthen and temperatures rise in many areas of Mexico, pressure and tensions surrounding water availability are also expected to increase. This competition may be on a local scale between individuals, on a national scale between states, or even internationally. Increased demand for water is predicted in at least seven states (Veracruz, Jalisco, Chihuahua, Coahuila and Guanajuato, Mexico City and the State of Mexico, which account for 45 per cent of the total population[33]); but the most vulnerable areas, with the highest costs for finding sources for water supply, are Mexico City and the State of Mexico.[34] In 2011, all of Chihuahua's sixty-seven municipalities suffered a severe lack of rainfall. As a consequence, the state refused to hand over water to the US, breaching its commitment to the 1944 International Water Distribution Treaty,[35] which requires Chihuahua to hand over 80 per cent of its river and dam water to the US. The governor of Chihuahua emphasised that his state is 'the only desert in the world that exports water. It is time to leave this water for the Chihuahuenses'. Farmers in Chihuahua, overwhelmed by the situation, forcibly took control of eleven municipal presidencies to demand solutions to the lack of water.

Water competition is also a major topic of debate at the international level. Despite co-operation between Mexico and Guatemala in the International Boundary and Water Commission (IBWC) and a smooth trans-boundary exchange of water at a community level, there seems to remain some disagreement at the national level. Guatemalans voice concern over the lack of compensation from Mexico for water that comes from Guatemalan territory into the Grijalva complex, which generates 47 per cent of hydroelectric power in Mexico. On the other hand, Mexico claims that waters which flow into Mexican territory belong to Mexico. In 2009, an inventory of the 'passage of trans-boundary water' was generated in order for each country to use water sources located within its own territory.

Diplomatic hurdles on water issues seem to still be present in both countries. In addition to a co-operation between Mexico and Belize on water matters through the IBWC, in 2009, CONAGUA established a Basin Management Programme for the Hondo River in order to address Belize-Mexico water-related issues and a hydro-environmental programme for the southern frontier in order to address trans-boundary basins. However, both programmes lack the full participation of Guatemala and Belize.[36] Despite these efforts, unfortunately, there is no tripartite agreement for the use of trans-boundary water between Mexico, Belize and Guatemala. Greater efforts are needed between the foreign ministries of these three countries to combine international initiatives at the local level.

Currently, the IBWC has neither the mandate for basin-related nor groundwater-related matters. This is a problem for the IBWC dealing with issues between Mexico and the United States; as one example, the All-American Canal re-lining project in southeastern California, conducted by US authorities, directly affects the Valley of Mexicali across the border in Mexico. The US project has substantially reduced aquifer recharge and has increased water salinity across the border. The effect has been a reduction in cultivation of 9 per cent by volume of the production area, and a 13 per cent increase in energy costs for producers as major volumes of water are needed.[37] Were the IBWC legal framework extended to groundwater- and basin-related matters, the agency could establish guidelines for the management and exploitation of underground aquifers in order to avoid problems like that seen in the Mexicali Valley. On a positive note, "Minute 319" has recently been signed by the US and Mexico setting a precedent for future co-operation on water management and the impacts of droughts and climate change.[38]

Water scarcity and competition is a significant social, political and environmental issue in Mexico. A cascade of events could exacerbate these problems; as water supplies for irrigation become scarcer and more expensive, this could lead to agricultural activities becoming unsustainable, in turn spurring an influx of people into urban areas searching for alterative employment. The arrival of these migrants puts further pressure on water supply in urban areas, and may lead to an increase in criminal activity, illegal commercial practices to supply water and potentially urban conflict. Water is a key consideration among many that could lead to conflict, and its main role is as a threat multiplier for conflict in already fragile situations; but, due to its necessity for all parties, it could also be used as common ground to lay the foundations for co-operation, as Minute 319 may achieve for the US and Mexico.

Food Security

Food security is associated with the efficient functioning of a country's food system to generate or acquire enough sustainable food supplies at the local, state and national levels in order to feed the population. More than 20 million people in Mexico are considered to live under circumstances of food insecurity, and between 2008 and 2010 alone almost 2 million people in Mexico were added to this group.[39]

Food security depends directly and indirectly on agricultural industry, water supply and the protection of natural ecosystems – for example, soil and water conservation, watershed management, combating land degradation, protection of coastal areas and biodiversity conservation.[40] Significant changes in climate conditions will affect the food-security dynamic through effects on all components of food systems at the local, national and even global level.

Changes in climate, such as the increasing frequency and intensity of droughts and the associated increase in salinity, accelerate the loss of arable land. Increasing irregularities in the rainy season, which might be influenced by climate change, will impact the groundwater level and have a disruptive effect on the production of food, the incidence of food crises, livelihoods and even human health in both rural and urban areas.[41]

Climate change will have different effects on individuals, based on factors such as gender, age, wealth and health – the impact of these variables on the decision to migrate having been discussed previously. Economic livelihoods based upon agriculture in many cases may in fact benefit from the effects of climate change, but others will be severely disrupted. Rural agricultural communities in or on coastal areas, floodplains, river deltas, mountainsides and drylands are at highest risk from extreme weather events. Individuals who lack adequate insurance coverage or security measures will become more vulnerable to climate change over time, and may eventually be forced to migrate.

Food availability is a major source of concern in Latin America as a whole. Mexico currently imports about half of the food it consumes, despite itself being a major agricultural producer. This large-scale importation reduces biodiversity and quells the opportunity for the agricultural industry to find adaptive measures to the changes in the climate and its consequences. Little more than 10 per cent of the food produced in Mexico is for the world market – the rest is grown for internal needs. However, population growth and unstable domestic food production are likely to mean that Mexico will become increasingly reliant on food imports in the future.[42] Production of maize in Mexico would be negatively affected by climate change, as the proportion of land unfit for its cultivation would go up from 59.6 per cent today to 75 per cent. Moreover, 8.4–22.0 per cent of land would be only moderately suitable for the production of maize, and only 2.5–15.9 per cent would be entirely suitable.[43] Another study warns that the conditions required for growing maize will become rarer, forcing the need to implement adaptive environmental measures.[44] To this end, initiatives such as 'Sin maíz no hay país' ('no maize, no country') emphasise the importance of agricultural products to Mexico.

Desertification seems to be also a key driver of the decision for individuals to migrate from rural communities in arid and semi-arid regions of Mexico. Some of these climate-induced migrants take part in the increasingly common urbanisation drive leading to Mexican cities; others look further afield, like the US. Analysts have estimated that Mexico is losing 400 square miles of farmland to desertification each year.[45] According to the governor of Durango, severe droughts have affected the indigenous communities of the region, like in El Mezquital where they have a self-sufficient/own-consumption agriculture. Recent reports estimated that 80,000 farmers have migrated to other destinations as the droughts have severely affected their source of income.[46] In agreement with these observations, reviewing the quantitative analysis in Table 10, we can see that an incremental increase in the mean annual temperature of Durango (in the Traditional migration region) has a positive impact on the decision to migrate both internally and internationally.

Maize producers in Mexico are adopting different strategies to tackle climate change and variability; this is an important example of the opportunities that climate change presents with regards to adaptive capacities. Such strategies may involve altering the area of cultivated land to sustainable sizes, changing the type of maize cultivated to a more resistant strain with a shorter cycle, changing the growing processes to minimise water loss, looking for alternative employment in other sectors or in urban zones, or, finally, migrating internally or internationally.

There have also been calls for the Mexican government to establish food reserves in order to buffer against price volatility due to market speculation. In theory, this would remove volumes of grain from the market and place it under sovereign control so that the poorest people are not be 'priced-out'.[47] However, the government does not currently consider strategic food reserves, especially of grain, as a necessity as the production methods have not yet been compromised. According to Support and Services for Agricultural Trading (ASERCA) in 2008, there is also deficient infrastructure for the collection, storage and conservation of agricultural produce. This study therefore suggests the government should adopt a more preventative rather than reactive approach, and consider grain reserves as part of the policy governing food security. However, considering Mexico's security landscape, the risks of such reserves falling under the control of criminal organisations must also be taken into careful consideration.[48]

Energy Security

One of the most problematic direct consequences of the energy sector's vulnerability to climate change is the impact on GDP that may arise as disruption to the energy sector filters down through all other dependent industrial sectors.[49] In Mexico City in 2008, power cuts led to a loss of 1.5 billion pesos ($112.4 million) for industry; the commercial sector in the city lost around 40 million pesos ($3.0 million) in just two days of not having electricity.[50] Previous analyses of Mexican energy security identify two different aspects of industrial sensitivity to climate change: those industries dependent on natural resources that are vulnerable to climate change, and industries where the industrial process itself is directly sensitive. The energy sector spans both areas of sensitivity and constitutes a critical pillar of the resource nexus. For example, electricity production often requires high volumes of water to generate steam and for cooling. Thus, a reduction in the amount of available water causes electricity operations to decrease up to the point of halting overall operations. This situation strains the energy sector, but it also poses a great challenge for other sectors heavily dependent on water: different sectors will compete for remaining water resources, adding further stress to the management and consumption of water for the population as a whole.

Climate change affects the function and operation of existing water infrastructure – including hydroelectric power, structural flood defences, and drainage and irrigation systems – as well as water-management practices.[51] Poor water infrastructure in Mexico causes approximately 40 per cent of drinking water and 50 per cent of irrigation water to be lost in leaks.[52] An example of how environmental change affects the functionality of dams was seen in 2007, when floods in Tabasco caused a landslide that created a bottleneck in the functioning of the regional dams. The Federal Electricity Commission (CFE) and CONAGUA had to work together to release the water flow while also providing security to the population surrounding the area.[53] Moreover, hydroelectric power represented 21 per cent (out of 52,567 megawatts total) of electricity generated in 2010 in Mexico. A disruption of this 'clean' energy necessitates the use of other, non-renewable sources, most likely coal. Therefore, the lack of water may also affects energy security and GHG emission reduction targets, which has been one of the most important climate-policy goals of the current government.[54]

Energy infrastructure is also exposed to the effects of environmental change – for example, transmission lines that carry electricity across. One particular problem is a phenomenon known as 'sag', which softens the transmission lines, causing interruptions to electricity supply. With increasing temperature will come more instances of sagging; coupled with increasing energy demand, this could lead to more outages.[55] An overloaded transmission line is a risk if, for example, it falls onto trees, causing short circuits and energy interruptions.[56]

Oil platforms and infrastructure along the Gulf Coast are also vulnerable to rising sea levels, potentially causing disruption to the energy sector in the region.[57] The interaction between intense waves and floating structures is the primary concern – 'green water loading' occurs when coastal platforms are swamped by waves on deck. There are over 150 operating oil exploration platforms in the Gulf of Mexico, each having a life expectancy of between thirty and forty years. These exploration platforms face some of the greatest risks of climate change: already, hurricane winds and intense waves commonly halt operations and force the evacuation of personnel, resulting in great economic loss. Between 2004 and 2005, hurricanes Ivan, Katrina and Rita severely damaged several offshore structures in the Gulf of Mexico.[58] Hurricane Rita alone caused the evacuation of fifteen oil platforms, reducing production by 877,000 barrels per day and helping push the price of crude oil up to $67 a barrel.

Tabasco is one of the most hydrocarbon-rich states in Mexico and, as a consequence, has significant related infrastructure such as wells, gas-processing plants and transportation infrastructure for oil and derivatives. During the 2007 floods, there was no major damage reported to any of this infrastructure, with the only damage being to highways used for transport routes and several petrol stations in the region – largely caused because highway construction had blocked natural drainage channels.[59] Equally important, the existence of these important oil installations in Tabasco has played a significant role in the distribution and concentration of people in both rural and urban areas.[60] People have moved towards these destinations for social and economic reasons, irrespective of the threats of regular flooding. The oil industry can therefore be thought of as a pull factor in the context of migration, which in this case acts in the opposite direction to environmental factors exposing individuals to greater risk. Reverting to the MLM model in Table 10, we can see that in the southern group (of which Tabasco is part) an incremental increase in the annual mean precipitation positively affects the decision to migrate – meaning that people are expected to leave the area. This result could be an indication that although economic pull factors have determined migration patterns, this trend could be affected by climatic forces, in which case it could increase the number of migrants leaving.

Mexico has one nuclear facility: Laguna Verde, in Veracruz. The location of the plant has raised considerable public concern in the past as the area is particularly prone to earthquakes, with at least one at event at 7 on the Richter scale each year.[61] The CFE insists that threats from hurricanes are of greater concern than earthquakes or tsunamis:[62] sea levels can rise up to 75 cm during a tsunami, and the plant has been designed to resist surges up to 5.45 m. The facilities are also designed to resist wind speeds up to 276.7 km/h, with the maximum recorded wind speed at the plant being 126 km/h.[63] A former minister of energy cited nuclear energy as one of former President Calderón's strategies to diversify energy production, and in 2010 Mexico announced a plan to build ten new nuclear power stations by 2028 – but this has been on hold following the Fukishima disaster.[64]

Summary
Investigation of the interconnections between the availability, distribution and competition over different resources is paramount to the understanding of CIM and the associated security risks in Mexico. In general, temperatures in Mexico are rising, precipitation levels are falling and the frequency and intensity of flooding and natural disasters pose serious threats to water, food and energy security. In turn, the availability of and competition over these key resources will alter the spatial distribution of people in Mexico. The Mexican authorities and public recognise that the primary effects of climate change have far-reaching effects. However, the secondary effects of climate change have perhaps received less attention, yet they are still of importance. One such phenomenon is CIM. Mexican policies so far to address migration and climate change have largely been reactive rather than pre-emptive.

CIM is not a matter that immediately necessitates military involvement; however, organised criminal groups in Mexico are identifying potential opportunities as climate-induced pressure builds on key resources. Criminal organisations are exploiting those incapable of migration, for example by illegally selling water at elevated prices to the poorest inhabitants of cities. Such situations could be prevented or ameliorated through municipal-level predictions of the changes in population that would allow for evidence-based resource planning, supported by strong communication between local and national governmental institutions. Mexico's National Security Strategy must fully appreciate that climate change is a threat to the preservation of resources and the wellbeing of citizens: protection of the availability and distribution infrastructure of these resources should feature in future plans.

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IV. Government Responses (2006–12)

Facing the significant challenges outlined in previous chapters of this report, the Mexican government and associated institutions have been actively developing diverse solutions to address climate change and migration, pushing forward adaptive measures and improving their strategies to maintain sustainable development and growth for Mexico. In this section we critically discuss some of the most relevant initiatives.

Mexico helped pioneer multilateral discussions on the human environment and climate change by taking part in the United Nations Conference on the Human Environment (the Stockholm Conference) in 1972, and the Earth Summit in Rio de Janeiro in 1992. Mexico has signed around a hundred international agreements related to the environment and sustainable development. It is a signatory country of the UNFCCC and the Kyoto Protocol. It has presented four National Communications to the UNFCCC and is currently preparing its fifth. Mexico was also the first developing country to submit a Fourth National Communication.

Mexico hosted the Conference of the Parties (COP 16) in 2010 in Cancún, where it promoted multilateralism; Mexican officials were applauded for their handling of the conference, which was seen by some to put the international debate on climate change back on track after the generally disappointing outcome of the 2009 COP 15 in Copenhagen. During COP16, Mexico proposed the creation of a Green Climate Fund, an initiative to provide financial support to projects intended to reduce GHG emissions. Its governing instrument was adopted in Durban at COP17 and, just recently, Mexico has submitted a bid to host the Green Climate Fund Headquarters in Mexico City.[1] Equally importantly, Mexico successfully advocated adaptation measures to be addressed with the same level of priority as mitigation. These efforts culminated with the adoption of the Cancún Adaptation Framework (CAF) as part of the Cancún Agreements. It is also important to note that Mexico hosted the Fourth Global Forum on Migration and Development (GFMD) prior to the COP16, and put climate change and migration on the agenda by dedicating a roundtable to their relevance and impact.

Mexico has also been a leading promoter of regional collaboration through many mechanisms, including the Mesoamerican Strategy for Environmental Sustainability (EMSA), to promote the greater integration of economic and social development and the improvement of human prosperity, with climate change being one of their key strategic areas – together with biodiversity, forestry and sustainable competitiveness. More recently, an Action Plan for EMSA has been adopted with twelve co-operative actions, including an Adaptation Programme for communities, ecosystems and production systems as well as voluntary mitigation actions on climate change and a network of Local Plans of Action on Climate Change (PLACC). Domestically, Mexican legislators have also been very active drafting several laws and adopting the new General Law on Climate Change. As Fernanda Sanchez, a former member of the Chamber of Deputies, explains:[2]

> The General Law on Climate Change is an exemplary instrument for many countries in the world, especially for emerging economies. The Law will apply throughout the territory and establishes powers and duties for all levels of government. Among its principal contributions is to address those most vulnerable to climate change, which are usually the poorest and most exposed, which could be important for future CIM policies. However, certain important consideration were left out of the Act such as (a) Creating a Mexican Official Standard on compounds or greenhouse gases and a network of weather stations to standardise the information, (b) Oblige municipalities to develop programs for climate change, and (c) add a goal of 0 per cent deforestation among others.

To build towards an effective climate change policy in Mexico, it is vital to obtain a regular and detailed evaluation of national circumstances, with region-specific vulnerability assessments of climate variability and extreme events. Equally important is the need to develop public awareness of the key issues facing Mexico and to design and analyse policies concerned with mitigation and adaptation to climate change.

In light of this, the Special Program on Climate Change (PECC)[3] was ordered by President Calderón to develop and consolidate the findings of the previously released National Strategy on Climate Change. The latter was prepared by the Inter-Secretarial Commission on Climate Change (CICC), which is comprised of representatives from the Ministry of Foreign Affairs (SRE), Ministry of Social Development, Ministry of Environment (SEMARNAT), Ministry of Energy (SENER), Secretariat of Economy (SE), the Ministry of Agriculture, Fisheries and Food (SAGARPA) and the Ministry of Communications and Transport (SCT), in order to demonstrate that it is possible to mitigate and adapt to climate change, without compromising sustainable development and growth.

The PECC sets out a vision and goals for particular sectors, but it does not provide specific procedures for achieving these. It has identified several key areas in which to mitigate the effects of climate change, with solutions to the most serious problems being outlined; in particular, the negative effects of climate change on the use and generation of energy prompted proposals for a carbon market between companies in the energy sector,[4] the promotion of natural-gas projects, additional investment in renewable energies[5] and reductions in the emission of GHG.[6] As of March 2012, the latter has achieved 44.51 $MtCO_2e$/year (metric ton carbon dioxide equivalent per year), showing an 87.86 per cent advance with respect to the 2012 target (50.66 $MtCO_2$ e/year).[7] Efficient, 'pro-poor' climate-change mitigation measures, such as sustainable agriculture and forestry management,[8] a shift towards rail-based cargo transport and the reduction of landfill emissions were also all highlighted by the PECC as areas where improvements could successfully mitigate the impact of climate change. In this regard, a recent study suggests with 80 per cent confidence that the PECC will mitigate between 29.5 and 48.4 $MtCO_2e$/year in twenty targets, representing a mitigation of 39.5 $MtCO_2e$/year.[9] It also addressed the importance of adaptive measures, and in particular of collaborating and harnessing existing institutional capacity through streamlining and integration.

The CICC has also approved the Mid-Term Climate Change Adaptation Policy Framework to bolster local adaptive planning and reduce differential vulnerability.[10] More recently, the government has adopted state-level Programmes of Action for Climate Change (PEACC). The PEACCs are support tools for the design of sustainable policies and action on climate change for state and municipal governments, taking into account the major social, economic and environmental impact on each state, the targets of state development and the state inventory of GHG emissions. The PECCs also highlight strategies to manage vulnerability to climate change and GHG emissions from natural and human systems.[11] Nuevo Leon, Guanajuato, Mexico City, Hidalgo, Veracruz, Puebla, Tabasco and Chiapas all have concluded their PEACC and many other states are currently developing one.

Other initiatives try to assess climate-change impact at the municipal level in order to develop the necessary policies for mitigation, adaptation and resilience. The Municipal Climate Action Plan is a project initiated by ICLEI – Local Governments for Sustainability, with the technical and institutional assistance of the Instituto Nacional de Ecología (INECC, under a new name and extended responsibilities) and is financed by the Embassy of the United Kingdom in Mexico. The goal is to develop thirty municipal action plans in 2012 and two hundred in 2013, representing 10 per cent of all municipalities in Mexico.[12] The need to implement adaptive measures to combat and deal with short-term effects of climate change has pushed Mexico to take further action. The government is therefore currently working on a national adaptation strategy (Visión,elementos y criterios para la construcción de la Estrategia Nacional de Adaptación a mediano Plazo/'Vision, elements and criteria for the construction of the mid-term National Adaptation Strategy', henceforth Mid-Term National Adaptation Strategy) to establish the necessary elements to guide policy instruments and actions needed to reduce vulnerability, increase resilience and enhance the adaptive capacity of society. Ecosystems and productivity will become a relevant input for the National Climate Change Strategy mandated by the forthcoming General Law of Climate Change of 2013. This is a good example of the right pathway for greater policy integration and planning, in which the CICC plays a crucial role. Policy integration is of paramount importance in constructing a climate-change agenda that is sensitive to CIM and security-related matters.

The Mexican government is actively engaged in preventative measures to reduce the damage caused by natural disasters and extreme-weather events. The Ministry of Social Development has established the Human Settlements Risk Prevention Programme, available to municipalities and delegations of Mexico City that are particularly vulnerable to hydro-meteorological and geological phenomena. The idea is to develop a natural-hazard or risk atlas to strengthen prevention and mitigation efforts in human settlements – for example, reducing land occupancy in risk areas, preserving natural systems, and further work and action to mitigate risks. Such atlases are only powerful tools if the people on the ground are aware of, have access to and understand the information in them. If the initiative proves successful and has the appropriate authority, then it should prevent populations from settling in areas at risk of flooding, landslides and potential disasters – and should furthermore be rolled out across wider areas.

Other planning tools include disaster-risk reduction strategies and other risk-management strategies, which aim to help to build resilience, reduce vulnerability and help support adaptation to extreme events.

Mexico also gave particular attention to disaster-risk reduction in its G20 presidency.[13] It received much praise for significant progress in preparing people for natural disasters, for example, when a series of earthquakes hit athe country throughout 2012. Mexico also plays an important role in the Regional Platform on DRR, which in 2011 recognised the importance of linking disaster-risk reduction and climate-change adaptation.[14] These include the integration of climate-change policy into disaster-management strategies, but could also include the integration of climate change and disaster-risk reduction strategies into national migration management policy and practice.

At present, Mexico has a network of centres and institutions to tackle natural disasters – such as the national system of civil Protection, a national atlas of risks, a national centre of disaster prevention, a seismic network, a tropical cyclones early alert system, and a monitoring network for active volcanoes – among other mechanisms such as the Fund for Natural Disasters (FONDEN) and the Fund for Disaster Prevention (FOPREDEN) to monitor and safeguard the population against future natural disasters and extreme-weather events.

FONDEN was created in 1996 with the purpose of efficiently assisting people affected by natural disasters, as well as public physical infrastructure that is not eligible for insurance. The purpose is to complement the local budgets for extra costs incurred.[15] The projected budget for 2012 gave the Ministry of Interior 23.5 billion pesos ($1.78 billion), of which 24.5 million pesos ($1.85 million) was earmarked for FONDEN – little more than 0.1 per cent of the total ministry's budget.[16] Although FONDEN financial reserves are reinsured, the budget allocation has come under significant pressure and there have been calls for its expansion as the government continues to spend more trying to cope with disasters rather than their prevention and mitigation.[17] It is important also to note that, regarding damaged physical infrastructure, the fund reconstructs affected areas the way they were prior to the disaster; this may be of concern if affected areas had very poor infrastructure before the disaster.[18] This fund should also consider the allocation of a portion of its budget to exclusively focus on the population relief, under which CIM could also be addressed.

FOPREDEN promotes preventative action to reduce the risk and the destructive impact of natural phenomena, as well as promoting the development of integrated risk-management studies, as well as applied research and technological development for disaster prevention and mitigation. The fund provides finance for the timely allocation and application of resources, according to the level of urgency. FOPREDEN operates with federal budget resources, thought it is smaller than the recovery fund, FONDEN.

Extreme-weather events and atypical situations such as the recent droughts – which appeared to be the worst in seventy years – have been addressed by the government with responsive measures such as the Agreement to Mitigate the Effects of Droughts,[19] which sees the collaboration and co-ordination of various ministries sharing responsibility and action. Such initiatives can certainly be used as a model for other agreements when addressing situations that require inter-secretariat co-ordination such as CIM. This particular initiative was only established at the beginning of 2012 as a responsive measure; looking to the future, it may become a valuable preventative measure that contributes to public wellbeing, GDP and Human Development Index (HDI) indicators. Studies show a significant impact from natural disasters, especially floods and droughts, on reducing HDI and increasing poverty levels in Mexico;[20] the impact on the former in affected areas was shown to be similar to two years' regression. These studies are significant for a country that is progressing economically and ranks 57th out of 169 countries in the HDI 2011, placing Mexico above the regional average.[21] The adoption of a more comprehensive, people-centric measure of sustainable development, that shows how climate change already poses severe long-term human development risks, will help countries like Mexico to better measure their achievements and what still needs to be done – a call that the United Nations Conference on Sustainable Development (Rio+20) put forward in the 2012 ‘Future We Want’ accord, signed by 188 nations.[22]

This report previously highlighted the importance of effective resource governance, management and distribution in light of the challenges faced by climate change and migration. Mexico has in place the necessary secretariats and institutions to address issues of key resources, including water (CONAGUA), food (SAGARPA), energy (SENER). This report now assesses some of the initiatives established by these bodies and their impact both within Mexico and internationally.

Water

Water is one of the most important resources for Mexico and is strongly connected to other key resources such as food and energy. The magnitude of the challenges facing water availability, distribution and management in Mexico makes understanding the strengths and weaknesses of the government’s strategy of paramount importance. In 2011, President Calderón admitted that Mexico had gone from being a country with abundant water resources one with ‘water stress’.[23] His government tried to give water issues a high priority in its agenda and treated it as a topic of national security. This is also stated in the National Development Plan and in the National Water Program, which defines public policies that ensure sustainable use of this valuable scarce resource.

The management and preservation of water in Mexico is an enormous task for authorities to deal with. CONAGUA, which is responsible for ensuring correct management and preservation of national waters, is actively engaged in many programmes and initiatives for the improvement of water efficiency, the increase of waste-water treatment and its re-use in urban areas. With its 2030 Water Agenda, CONAGUA promotes a long-term vision for the future of water resources in Mexico. In collaboration with the WWF and the Inter-American Development Bank, CONAGUA is developing a scheme of water reserves for environmental use, defining areas where ecosystems are included as users of water and protecting the necessary amount of water for their proper functioning.

CONAGUA has also been very active in responding to the severe droughts and floods that Mexico has experienced over the last two years. At the beginning of 2012, the Agreement to Mitigate the Effects of Droughts allocated 34 billion pesos ($2.5 billion) intended to solve the problems posed by drought in nineteen states.[24] This will allow CONAGUA to allocate nearly 4 billion pesos ($300 million) to improve water supply for human consumption and agricultural production in states affected by drought.[25]

At the international level, CONAGUA is helping Mexico to maintain its leadership in advocacy on water and climate-change issues. It participates in all the major forums, promoting international collaboration as crucial to the future of water management in Mexico, Latin America and globally. The fact that the Water Centre for Latin America and the Caribbean has its headquarters in Mexico shows the international leadership that Mexico has in this matter. Other important institutes such as the Mexican Institute of Water Technology[26] and the Water Advisory Council[27] are essential in the awareness, research and initiatives for the preservation and management of water.

Despite these efforts, there are still some areas for improvement; for example, stronger policies for resolving the differential cost of water, low rates of water payments, uneven distribution between arid and non-arid regions, high subsidies and a sporadic public reluctance to pay for essential services – all of which hinder the management and distribution of water. Access to water in the peripheries of major cities is already reaching critical levels and it is even more volatile in rural areas.[28] Deficiencies in water infrastructure are also a major problem – 45–65 per cent of water destined for agriculture is not used due to losses. In the cities, at least 50 per cent of water is lost due to leaks in the drinking water distribution system.[29]

Agriculture

The Mexican government is aware of the importance of food sovereignty and its ability to produce, export and distribute it in an equitable way. Having undertaken a number of surveys, the government is trying to measure the magnitude of food insecurity in the country; the results show that 52 per cent of the population suffers from some degree of food insecurity.[30]

In order to address and prevent damage caused by climate change on agriculture and fisheries, between 2008 and 2012 SAGARPA launched a series of mitigation and adaption programmes to better manage risks and reduce vulnerability in the agriculture and fishing sectors. It established the General Directorate for Attention to Climate Vulnerability in the Agricultural Sector and Institutional Concurrency within the CICC.[31] Internationally, Mexico also led food security talks at the G20 in 2012 and, under the G20 Agriculture Group, established the implementation of the action plan adopted in 2011 to address food security challenges.[32]

On a local and state level, Mexico also has in place a series of insurance schemes to support its famers and the agricultural industry. Insurance is one of the most important instruments for agricultural development in any country; it protects against adverse climate losses, stabilises incomes, controls government spending and stimulates employment. Only 0.68 per cent of Mexican producers have insurance for production.[33] This may seem like a low level, and it should be improved, but it is worth noting that 'of all the countries in Mesoamerica, Mexico has the best penetration of insurance in the agricultural sector. Levels of premiums and hectares covered are large and a broad range of risks and crops is insured.'[34] In 2010, 10 million acres were insured in Mexico; 49 per cent through private institutions, 40 per cent through Agroasemex, and 11 percent through insurance funds. Agroasemex, the state reinsurance company, offers protection in the form of an index insurance programme for federal and state governments, which effectively transfers risk from the government to the reinsurance market.[35]

SAGARPA, through Agrosemex, will provide catastrophic insurance to provide protection of an estimated 6.3 billion pesos ($481 million) over at least 2.1 million hectares at risk associated with climate change in the country's agricultural activities.[36] Mexico is also addressing the needs of low-income farmers through the Assistiance Fund for Rural Population Affected by Climate Contingencies (FAPRACC) which is a reserve pool for small farmers affected by catastrophic weather events, who might not have access to public or private insurance and who do not have the solvency to be members of a fund or the Programme for Prevention and Management of Risks. The assistance fund aims to help low-income producers back into their normal activities after extreme-weather events. However, these initiatives can be undermined by delays in the delivery of these funds, especially to marginalised areas, the lack of registers of affected population or mapped information of the most vulnerable locations, which receive these funds most often. Additionally, many small producers might not know the existence of these initiatives, even though there is co-ordination between the federal and state authorities. Therefore, there should be more programmes and incentives for small producers to become familiar with available insurance products.[37] The current droughts that Mexico is experiencing are a window of opportunity for increasing awareness and incentives among vulnerable farmers and producers: the more they are insured, the faster the policy costs will go down. This could also prevent farmers and producers resettling somewhere else once they have lost their crop as the economic incentive of been compensated will help them to re-start their business.

Since 2004, Mexico has conducted annual national health polls. In 2012, this survey for the first time included questions that will directly help determine the number of individuals living in food insecurity. The results, which will be presented in 2013, could become a very useful indicator of the amount of people that are not only exposed to food insecurity, but, due to the resource nexus, are also at risk of water unavailability, health insecurity and might decide to migrate in search of vital resources and better quality of life. Mexico has been a leader in conditional cash transfers, aiming to combat poverty by helping low-income families invest in human capital (focusing on education, health and nutrition). The Oportunidades programme provides cash assistance to families – amounting to the equivalent that families would have if their children were sent out to work instead of going to school – but the aid is conditional upon monitored school attendance and health clinic visits. About a quarter of the Mexican population is active in the programme, which accounts for 46.5 per cent of the total federal anti-poverty budget – about $3.26 billion.[38] In terms of the number of families receiving aid per state, from a total number of beneficiary families of 5.8 million, Veracruz and Chiapas top the list, with 662,609 and 620,681 respectively.[39]

Referring to the regional quantitative analysis in Tables 9 and 10, the probability that people will decide to migrate internally from Veracruz and Chiapas increases with more precipitation, but this tendency could be reversed with programmes such as Oportunidades, which could lessen some of the social costs of climate change on vulnerable populations – and thereby lessen the need to migrate, at least in slow-onset situations. Additionally, if the years of schooling of a household member increases, then the probability that he or she will migrate internally decreases, showing the positive effects of focusing in education as a strategy to reverse migration.

Energy

The Calderón administration expressed commitment to the reduction of GHGs and thus has begun the use of renewable energies to diminish dependency on fossil fuels, as well as promoting efficient energy use.[40] President Calderón also developed a national strategy to improve the infrastructure, transportation and commercial distribution of natural, including a public-private investment of about $7.9 billion to build gas pipelines. The official discourse is that natural gas constitutes a priority of the Mexican energy policy, which nevertheless aims to diversify energy sources to reduce dependency.[41]

Mexico has implemented various measures in a drive to cut GHG emissions. These include a programme to plant 250 million trees and increasing the amount of protected areas to 3 million hectares; establishing a GHG programme that involved forty-five companies in various sectors; projects promoting renewable energy; and the upgrading of transmission lines through the Clean Development Mechanism to reduce technical losses.[42] More recently, the adoption of the General Law on Climate Change binds Mexico to reduce GHG emissions (30 per cent by 2020, and 50 per cent by 2050) and increase the use of renewables (to 35 per cent of total energy by 2024). This remarkable move made Mexico the first developing country to make such binding commitments, and the second globally to the UK.

Production of fossil-fuel energy Mexico is expected to see a sharp fall off after 2020. This could seriously damage government revenue, which derives 36 per cent of its total revenue from these activities. Meanwhile, domestic energy demand will grow at 3.2 per cent annually over the same period.

The National Energy Strategy report, 'The Future of Energy', has planned to account for this by developing deep-water oil and gas, with the hope that these revenue streams come online before 2020. Some experts have deemed this seven-year development plan as overly optimistic. The National Energy Strategy report also highlights that Mexico currently has inadequate capital and technology to develop deep-water exploration. Other plans outlined in the report include renewal of oil and gas port infrastructure in Veracruz, upgrading of PEMEX's oil spill specialist vessels and, importantly, a commitment to energy efficiency.

The future energy security of Mexico is uncertain. With such severe economic implications coupled to political and social systems, detailed adaptive and preventative plans are a necessity. Climate change is a particularly important risk factor affecting energy as a resource and efficient and resilient infrastructure is critical to sustainable development.

Infrastructure

Climate change is a serious risk to the security of infrastructure. The increased frequency of extreme-weather events, rising temperatures, rising sea levels and large-scale changes in precipitation patterns are predicted to affect Mexico over the coming decades. Water, energy, telecommunications and transport infrastructure may all be exposed to damage if adaptation against climate change is not implemented correctly. The consequences of this could be severe with disruption to supply lines, operational barriers and increased resource competition.

The security of infrastructure is fundamental for Mexico. This includes not only the physical security of critical infrastructure (airports, hospitals, roads, oil platforms, etc) mostly located in coastal areas exposed to hydrological events, but also the security of individual houses and buildings in peripheral areas subjected to many risks, including floods and landslides, especially in urban areas. Local authorities not only need to spend time and money developing legislation to ensure that new constructions meet the highest standards, but equally importantly they need to monitor buildings and construction that will still be active in thirty years' time, implementing adaptation work if they are still to be used. Infrastructure adaptation goes hand-in-hand with city planning, especially for cities, such as Cancún, that are growing exponentially but in an uncontrolled manner, posing major problems for local authorities, the tourism sector and the wellbeing of residents – case studies done by the Mexican Institute of Water Technology and SEMARNAT are extremely useful in this regard.[43]

Building resilience into the urban infrastructure starts at the individual level. In the same fashion as programmes and initiatives that look to educate the population and make them aware of the availability and management of scarce resources such as water and food, it is equally important to address their behaviour to make their households resilient and implement quicker event planning in urban flooding situations, which are predicted to become more frequent and more dangerous in the future. Through the General Law of Civil Protection, the national system of civil protection has been developing and implementing policies to prevent, mitigate and respond to large-scale risks. In an attempt to share and learn best practices with other countries, the Mexican government has an agreement with the OECD for it to scrutinise the services of civil protection.[44]

The General Coordinator of Ports and Merchant Marine has presented studies on coastal erosion and beach protection and is both actively promoting initiatives for the preservation of marine ecosystems and assessing the vulnerability of the major ports in country. There is recognition that erosion is becoming an increasing issue in ports such Lázaro Cárdenas in Michoacán; maintaining functional ports is critical for trade and the movement of peoplem and even as platforms for humanitarian support following environmental disasters.

Security Strategy

In Mexico, the concept of security has been addressed as an issue that only pertains to traditional security institutions, such as the police and armed forces. Article 5 of the current Mexican National Security Law (2005) does not include natural disasters in the list of threats to national security. Since 2009 in the Mexican Congress, there has been a formal legislative process for reform, including amendments to the current National Security Law, but they are pending approval. This means, among other aspects of the law, that there is an ongoing effort to reform and redefine the national security concept to encompass a broader definition that includes natural disasters and climate change as potential threats. On the other hand, legal reforms propose radical changes in matters of security policy, reinforcing and enhancing the military role in internal security issues. It is important to note that the leftist PRD also proposed an alternative National Security Law initiative in April 2011 to redefine the national concept of human-security criteria, including natural disasters as threats to national security.

The issue of natural disasters is well appreciated among the armed forces, and this is reflected in the National Security Programme 2009–12.[45] Despite the exhaustive list of actions required from the military in this programme, there is no explicit mention of climate change as a threat to national security nor its implications on the sovereignty of critical resources and infrastructure. The programme advocates for an updated assessment of the vulnerability of airports and ports, but other key infrastructure such as hospitals, schools, telecommunications, oil and gas pipelines are also of great importance. Although the programme places human security at its core, there is no mechanism to account for the movement of people in the context of climate change and environmental degradation. Close collaboration with the INM could facilitate progress in this area if it appreciates the possible link between climate change and migration at the Mexican borders.

The Centre for Intelligence and National Security (CISEN) has also been increasing its activity in the field of natural disasters and climate change, by providing the necessary capacity to its analysts to address the issue of environmental change and its effects on Mexican resource security. These efforts could culminate in the creation of a new department that covers climate-change-related matters in the manner of the Centre on Climate Change and National Security established by the Central Intelligence Agency in the US.[46] Its focus is not the science behind environmental changes, but the effects on national security of processes such as desertification, rising sea levels, population shifts, and increased competition over natural resources – all the topics highlighted throughout this report.

Current legislative efforts to open the debate, and broaden the definition of security to include matters of social and political stability, have been unsuccessful. This must be resolved, since a failure to broaden the concept 'would complicate the design of efficient public policies and legislation on national security related to migration and climate change'.[47]

Equally important is the recognition of resource sovereignty as a threat to national security. One of the most important linkages between climate change, migration and security takes the form of competition over key resources such as water, food, land and energy. Competing actors not only include farmers and industry, but also non-state actors such as the powerful drug cartels in Mexico. These criminal organisations are diversifying their income streams, shifting some of their operations to other commodities and services, encouraged by high commodity prices. Thus, water, food and energy become extremely vulnerable as they could fall in the hands of these actors – a situation that is already happening in certain areas of the country. Intelligence-gathering in this matter becomes paramount, and the CISEN could positively contribute by including climate change as well as water, food and energy insecurity and its implications on human movement in the Annual Risk National Agenda that it develops for the National Security Programme and is approved by the National Security Council. The National Risk Agenda is updated periodically depending on perceived threats to the national development and security. These risks include natural disasters and manmade disasters.

Migration and Climate Change

The Institute of National Migration (INM) is an independent agency under the Ministry of the Interior, which applies current immigration legislation. It focuses on the international movement of people, and does not account for those that migrate within Mexico's borders. The Centre for Migration Studies (CMS) at the INM is part of the new Migration Policy Unit,[48] a provision established by the new Regulation of the Ministry of the Interior Migration Law. The CMS is responsible for providing an area of conceptual, analytical and statistical analysis – in the context of Mexico as a country of origin, transit and destination for migrants – to the INM, Ministry of the Interior and to the undersecretary for population, migration and religious affairs, for decision-making and management evaluation of national immigration policies. The Migration Policy Unit will also have an advisory council, while the INM maintains its Citizens Advisory Council. The latter will make recommendations to the INM based on expert, academic and civil society input, while the advisory council will gather inter-secretariat views and recommendations. The Migration Policy Unit is also developing electronic platforms and databases – named 'observatories' – of migration flows that will be open to the public.[49]

In 2006, the CMS included a special module for those affected by Hurricane Stan in the Migration Survey of the Southern Border (EMIF South) in order to assess the possible influx of migration from Guatemala to Mexico. However, the results showed that only 5.5 per cent of the respondents that lost their job due to the Hurricane Stain were changing residency, with 4.9 per cent relocating to Mexico and 0.6 per cent to the US.[50] These results did not encourage the CMS to continue with these type of surveys and, in fact, in the Survey of Migration for northern and southern border regions of Mexico (EMIF North and EMIF South), there is currently no mention of environmental degradation as a possible factor for migration. A council composed of representatives of the Secretary of Labour, Secretary of Health, CONAPO, SRE and INM decide on the modules to be included in the EMIFs, which are run by the College of the Northern Border (COLEF). The inclusion of a new temporal module with questions related to migration due to extreme-weather events and environmental degradation could be contemplated: while it does not add any cost to EMIF surveys, not all the members of the Council need to agree on this action unless direct instructions are given from SEGOB or the Office of the President.

Moreover, Mexico's new Migration Law also made no mention of climate change and extreme-weather events as one of the many factors in the decision to migrate. Articles 41 and 42 of the Migration Law contemplate migration for humanitarian reasons, granting a visa to migrants 'on grounds of major force' (*causas de fuerza mayor*). The latter could imply that migrants, due to environmental degradation and extreme events, could be embraced under these articles. Additionally, the definition of migrant includes neither environmental degradation nor extreme events as one of the many pushing and or pulling factors for migration.

Presumably, one of main reasons why the INM has not taken major action on matters related to climate change is due to the absence of any actions related to climate change and migration in the National Strategy on Climate Change in the short-term 2007–12 and in the medium term up to 2030. The INM did take part in the organisation of the Fourth Global Forum on Migration and Development (GFMD) held in Mexico in 2010 along with the SRE. In 2012, the INM together with the International Organisation for Migration (IOM) launched the book, *Global Perspectives on Migration and Development: Puerto Vallarta and Beyond*,[51] which dedicates a chapter to climate change and migration. Also in 2012, the Director of Research at the CMS released *México: Una política migratoria de puertas hospitalarias* (*Mexico: A Migration Policy of Friendly Doors*)[52] in which the author dedicates a chapter to climate change and migration in Mexico. Additionally, the CMS, on behalf of the INM, has collaborated with RUSI in the release of two reports on climate change and security in Mesoamerica.

In terms of internal displacement, the Migration Policy Unit does not account for internal migration and there is no special unit that can cover this task. Officially, the INEGI monitors the internal movement of people within Mexico at a statistical level. The new Observatory of Forced Internal Displacement, run by the Mario Molina Institute, has started to monitor internal displacement, but it would be advisable to do this in concert with a governmental institution that can monitor internal movements due to other reasons – including violence, poverty and environmental degradation. In this regard, there is the need of further monitoring of migration as a multi-causal phenomenon internally as well as internationally.

Policy Recommendations

1. Increase awareness and recognition of climate-induced migration in Mexico.
The newly approved General Law on Climate Change, and the associated fund, addresses those communities most vulnerable to the effects of environmental change and assesses their inclusion in adaptation programmes. However, this law does not recognise climate change as a fundamental factor in the decision to migrate, bearing in mind that the recognition should not be applied as a separate category, but as part of one of the many factors that induce migration. Despite these limitations, this law establishes a legal framework on the effects of climate change, especially on the most vulnerable population. Mexico's recent Migration Law also made no mention of climate change and extreme weather events as one of the many factors in the decision to migrate. We propose that legislators should recognise the contributions that environmental changes have and will continue to have on migratory patterns in Mexico. Additionally, the National Security Law does not recognise climate change or extreme-weather events as potential threats to the security of the country. We suggest that the CISEN should

include climate change as well as water, food and energy insecurity and its implications on human movement in the Annual Risk National Agenda that it develops for the National Security Programme.

2. Co-ordination and management.
Establish or designate an institution (or network of institutions) with the capability, authority and support to monitor and co-ordinate migration responses and resettlement related to environmental changes. The INECC in co-ordination with the CMS on behalf of the UPM-SEGOB could possibly perform this role for international migration, blending science, operational expertise and policy. A similar role could be adopted by a newly created unit to monitor internal migration. An NGO that already performs such a role for internally displaced people is the Observatory of Forced Internal Displacement. These institutes could establish a network for the research, monitoring and implementation of adequate policies for CIM, leveraging existing funds that could be supplemented through awards from the adaptation fund for climate change that is managed by the Mexican Institute of Water Technology as the National Implementing Entity (ENI).

Additionally, the national consensual strategy of the 'Visión,elementos y criterios para la construcción de la Estrategia Nacional de Adaptación a mediano Plazo', to be presented in 2013, will align well with these interdepartmental co-operative approaches. We also recognise the efforts of the Comisión Nacional de Derechos Humanos (CNDH), which is developing a protocol to care for internally displaced people in Mexico, in order to establish an obligation of the state to provide assistance.

3. Data collection.
Advise federal entities, municipalities, public and private research institutions to consider the collection of higher-resolution climate and demographic data, as well as ecological degradation and resource depletion data, than what is currently available, and collate this into a national, publicly available database. One practical benefit of this is that national and state governments, property owners, town planners, civil engineers and architects could use detailed information about the areas most vulnerable to rising sea levels to build physical defences, to design resilient architecture and urban spaces, and to encourage communities and individuals to make climate-change plans.

Here, we also recognise the efforts of the Mid-Term National Adaptation Strategy' (Visión, elementos y criterios para la construcción de la Estrategia Nacional de Adaptación a mediano Plazo to promote the involvement of sub-national actors in the collation and learning from their experiences of adaptation at a local level. In this regard, we recommend the inclusion of a wider range of adaptation alternatives available for vulnerable populations in order to prevent forced migration and displacement. Programmes on climate change currently under development at the state level should also include migration dynamics, paying particular attention to the areas most vulnerable to climate extremes. Additionally, the INM should reconsider the inclusion of a permanent or recurrent module in the EMIF North and EMIF South for the collection of data on CIM.

4. Annual vulnerability assessment.
Complementary to the efforts behind INE's Vulnerability Atlas of Mexico, standardised CIM vulnerability indicators should be agreed, coupled with formal annual assessments at the national, state and municipal level. Assessment committees would ideally be formed through inter-disciplinary collaborations between academics, state and government officials to enable evidence-based decision making at the local, state and national level. The CISEN should establish a Climate Change Centre similar in aim to the existing centres in other countries' intelligence agencies.[53] This would facilitate the dissemination of detailed and accurate information between academics and the government.

5. Managed migration opportunities.
Migration may also be used as part of an adaptive strategy. For example, for internal migration, the north of Mexico is becoming increasingly arid and the south increasingly arable; the planned relocation of skilled agricultural workers from the north to the south could be beneficial to both the migrant and the host communities. Managing sustainable development is imperative for rural-urban migration in order to avoid people moving to unsafe environments. The current programmes on climate change that are being developed at the state level and in some instances at the municipal level should integrate migration as a potential adaptive mechanism and include policy instruments to adjust, correct and extend adaptation policies.

For international migration, a possible adaptive strategy could be through managed migration to the US and Canada. Although undocumented migration to the US is at net zero at the moment, it may increase again when the US economy recovers. Therefore, it is a good time to assess the options for legal and managed migration, considering the increasing use of the seasonal agriculture and non-agricultural admissions programmes by Mexicans who will acquire the necessary know-how to be applied at a later stage in their country of origin.

6. Information dissemination.
Promote dissemination of detailed historical as well as current information related to changes in the climate, so that people are aware of the dangers of the areas in which they live, improving their ability to respond and adapt. This could take the form of comprehensive, municipal-level, publicly available

risk atlases that build upon existing efforts, such as the development of the Vulnerability Atlas of Mexico that the INE is currently undertaking. The Mexican diaspora can also play an increasing role in the transfer of knowledge to their communities of origin and channel remittances that can help local sustainable development and adaptive climate-change policies. Established governmental programmes, such as the Institute for Mexicans Abroad (IME), could certainly catalyse the diaspora's help to support alternative livelihoods for rural populations and scientific research on mitigation and adaptation strategies.

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V. Conclusions

Investigation of the interconnections between the availability, distribution and competition over different resources is paramount to the understanding of CIM and the associated security risks in Mexico. In general, temperatures in Mexico are rising, precipitation levels are falling and the frequency and intensity of flooding and extreme weather events pose serious threats to water, food and energy security. In turn, the availability and competition over these key resources could alter the spatial distribution of population in Mexico. The Mexican authorities and the public recognise that the primary effects of climate change have far-reaching impacts. However, the secondary effects have perhaps received less attention, yet are still of importance. One such effect is CIM.

The phenomenon of migration is complex and interwoven between demographic, social, political, economic and environmental push and pull factors. Our literature review shows that an individual's decision to migrate is influenced by a large and complex array of macro-, meso- and micro-level issues. Resolving such a complex process into its constituent elements and quantifying their weight upon the decision to migrate is clearly not straightforward. For this reason, it is only in recent decades that considerable progress has been made in unravelling this complexity and a consensus is evolving around the importance of environmental factors behind the decision and ability to migrate. Consequently, empirical work on the topic is starting to suggest that the evidence base in support of the phenomenon of CIM is growing, and is giving governments the confidence to further support this work and future investigations into the adoption of the necessary preventive rather than reactive measures.

To provide a more robust foundation for these discussions, a quantitative model was also developed in this research to explore the statistical significance of links between climate change and migration. The model provides a platform to fully explore the impact of climate change on migration with outputs at national and regional levels using municipal-resolution climate data, environmental data and demographic data as inputs. The model is not a predictive tool that can give absolute numbers of the migrants and their destinations; however, it does econometrically demonstrate the impact of several key variables (both demographic and climatic) on the decision to migrate internally or internationally. Our quantitative analysis confirms that environmental factors such as precipitation levels and temperatures are statistically significant in the decision to migrate in Mexico.

The most significant challenge in developing a model of this complex scenario has been to establish, in an appropriate and comprehensive manner, the way these multidisciplinary relationships develop at the moment the decision to migrate is made, as there are many social, demographic, economic, political and environmental issues involved in this decision. Future developments to the model could yield even greater detail, reaching outputs on the state level in the first instance and potentially to the municipal level, which could be supported by a qualitative analysis based on interviews and field work. From the results this research study presents, it will be possible to incorporate further evidence on the relationship between climate change and migration in Mexico on the premise that there are further climatic factors that also contribute to the migratory flows. Policy-makers should view this report as a first step towards the qualitative and quantitative understanding of the relationship between environmental change, migration and security. Some potential links between these three fields have been demonstrated, but much work has still to be done to provide more conclusive evidence of a link between climate change and migration and its security implications.

The demonstrated relationship between climate change and migration should encourage research that incorporates microeconomic general equilibrium models, where possible, to quantify the flow of individuals belonging to migrant and non-migrant households to destinations outside their place of origin. The implementation of quantitative models incorporates additional evidence in the study of CIM, and could identify areas with the highest number of migrants who have been influenced by climate change. The topics addressed by CIM are clearly cross-disciplinary issues, and require co-ordination of various fields of study in different research centres to share efforts and knowledge in order to be able to develop more complex models for more conclusive and definitive results.

In this era of economic globalisation and global climate change, it is necessary to place more emphasis on issues related to environmental factors in delineating migration patterns internally and internationally. For, if we ignore this key part of the process, we will be ignoring a key feature that will determine social, political and economic conditions in the coming years. Additional qualitative research should continue to search for evidence supporting or disproving the observations from quantitative analysis, and could be supported by surveys, interviews and data collection as detailed in our recommendations. Such research should also aim to further assess the extent to which CIM is being used as an adaptive strategy that can facilitate policy-making and adaptive responses and resilience to climate change.

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Appendix A: Definitions

Climate Change

The IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation released in March 2012 defines climate change as 'a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties that persist for an extended period, typically decades or longer. Climate change may be due to natural, internal processes or external forcings, or persistent anthropogenic changes in the composition of the atmosphere or in land use'.[1]

Migration

There is no internationally accepted definition for the term 'migrant'. However, this term is defined by the International Organization for Migration (IOM) as the movement of people, either across an international border, or within a state. Migration includes 'any kind of movement of people, whatever its length, composition and causes; it includes migration of refugees, displaced persons, economic migrants, and persons moving for other purposes, including family reunification'.[2] In this report we adopt this broad definition, but exclude displaced persons because we view their movements as non-voluntary while migrants may also choose migration as an adaptation strategy and/or as a voluntary practice.

Displacement

The term 'displacement' is used to refer to involuntary or forced migration, where people are relocated out of necessity rather than choice. The IOM defines forced migration as any person who migrates to 'escape persecution, conflict, repression, natural and human-made disasters, ecological degradation, or other situations that endanger their lives, freedom or livelihood'.[3] Additionally, and considering displacement only within a country's borders, the 1998 UN Guiding Principles on Internal Displacement define an internally displaced person (IDP) as one who is 'forced or obliged to flee or to leave their homes or places of habitual residence, in particular as a result of or in order to avoid the effects of armed conflict, situations of generalised violence, violations of human rights or natural or human-made disasters, and who have not crossed an internationally recognised State border.'[4]

Climate-Induced Migration[5]

The term 'climate-induced migration' is defined for the purpose of this research as migration which can be influenced by any form of change in climate, without isolating the impact of climate change from other factors that cause people to move. Such movements may be temporary or permanent and may be a direct result of climate change, for example in the case of continued flooding, or indirect in the case of increasing temperatures leading to desertification and the loss of arable land and consequently the destruction of people's livelihoods. In the current literature available on climate-induced migration terms such as climate migration, environmental migration or climate refugee all have similar connotations. It is important to note that CIM is part of the broader framework of migratory dynamics. Therefore, this study does not consider those affected by CIM as a separate category of migrants, but rather groups CIM with other drivers of migration.

Security

In international politics, security is typically conceptualised as an intent to protect against threats to national territorial boundaries and the sovereign rights of the state. Following the precedent set in previous work,[6] the current research reconceptualises security in two ways: first, by including threats to security which emerge from beyond the military sphere; and second, by addressing the security of individual human beings, as well as the state. Accordingly, the security of both individuals and the state is assumed to rest on political, social and economic stability. Issues including, but not limited to, mass migration, serious organised crime, resource scarcity and pandemic disease, which can potentially undermine such stability, are therefore taken seriously as challenges for security communities around the world. Among the sources of insecurity that communities fear are violence and the worries about how they will feed their families and keep them healthy. The latter helped to enrich the discussion of empowerment in the context of human security, with a focus on individuals and communities building their own resilience to current and future threats rather than being dependent solely on outside actors taking care of them as has been acknowledged in the 2003 report published by the Commission on Human Security, co-chaired by Sadako Ogata and Amartya Sen.[7]

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Appendix B: Theoretical Considerations

Discrete choice models are based on utility maximisation theory (Small and Rosen, 1981; Parsons and Needelman, 1992). For this reason, we model migration decisions based on a comparison of utility levels attainable under different migration statuses (Mora and Taylor, 2005; Olatomide and Awoyemi, 2012). A migration status is defined as a choice of place to live: in the case of non-migration, the village of origin, internal migrant destinations, or foreign destinations. An individual at location i faces j choices, including moving to a different area or staying at the current location. In a destination choice model if the utility of individual i choosing choice j is represented as U_{ij}, then choice j will be chosen if and only if $U_{ij} > U_{il}$ for $j \neq l$.

Because researchers do not know U_{ij}, the individual's true utility, they cannot tell for sure what an individual will eventually choose. U_{ij} consists of two components, the observable and the unobservable components:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \qquad (1)$$

U_{ij} consists of a predicted utility, V_{ij}, observable based on the choice's attributes, and an unobserved random component, ε_{ij}. If ε_{ij} were known, researchers would know U_{ij} and could tell for sure which destination would be chosen. Since researchers do not know ε_{ij}, the best they can do is predict the final outcome in terms of probability.

Assume that the utility of assigning individual i to choice j is given by:

$$U_{ij} = \beta_j Z_{ij} + \varepsilon_{ij} \qquad (2)$$

where Z_{ij} is a vector of characteristics of individual i, her family and community that influence utility associated with status j, β_j is a vector of parameters representing the returns, in utility, to each of these characteristics in status j, and ε_{ij} is an individual-and-destination specific stochastic error. This is a random utility model, in which the utility associated with pairing a given individual with a given migration status includes an observable, deterministic component, as well as an unobservable, stochastic one, as we mention above (Davies et al., 2001; Parsons and Jo, 1995).

The nature of the utility function merits some discussion. In an individual decision-making model, utility refers solely to the individual (although the individual might take into account the welfare of the rest of the individual's family in the source area for altruistic or other motives; see Rapoport and Docquier, 2006, Lucas and Stark, 1985). In a household migration model, utility refers to the entire household, which may or may not include the migrant (Taylor and Adelman, 2003). (Population census definitions of households, based on inhabitants of dwellings, usually exclude those who have migrated.) More generally, the relevant utility is a weighting of the individual's and household's welfare:

$$W_{ij} = \alpha_j U_{hj} + (1 - \alpha_j)U_{ij} \tag{3}$$

where U_{hj} is the utility of the individual's household at the place of origin, U_{ij} is the utility of the individual, and α_j is a welfare weight which may depend upon the choice of migration status. A weight of $\alpha_j = 1$ implies that no weight is attached to the individual's utility when the migration decision is made (a pure household model), while a weight of $\alpha_j = 0$ implies that no weight is attached to the household's utility when the individual chooses whether or not to migrate (a pure individual model). In real life, the relevant welfare function almost certainly lies somewhere between these two extremes ($0 < \alpha_j < 1$).

Two major determinants of utility are the income the household receives independent of individual i's status choice, y_{oh}, and the income the individual generates under alternative migration regimes, y_{ij}. Household income y_{oh} is the sum of net incomes from all household production and labour activities, excluding individual i. This income depends on family characteristics, ZF_i, it also may be influenced by context variables that influence the returns to family resources inside and outside the village of origin. An example of ZF_i might be access to outside markets for family farm production or migrant networks that influence remittances from other family members besides person i.

Non-migrants have the option of supplying labor to local labor markets or to family production activities. Those who participate in the labor market receive a wage that depends on their human capital, ZH_i, and context variables that influence the returns to human capital in local labor markets. Non-migrants who work in family production activities produce a value product that depends on family, community (ZC_i) and human capital variables. Migrants receive a wage that depends on their human capital as well as family and community variables influencing migration success (e.g., migration networks; see Woodruff and Zenteno, 2007; Massey, 1987; Taylor, 1986 and Munshi, 2003).

Individual, family and human capital characteristics may affect remittance behaviour as well as migrant wages. They also may affect the relative weight attached to individual and household utility. When a person migrates, the household's welfare depends upon the migrant's earnings, her willingness to share these earnings with the household through remittances, and the weight attached to the welfare of the migrant vis-a-vis the household. The impact of a given variable on migration probabilities is a mixture of influences on incomes at origin and destination, remittance behaviour, and welfare weights. We do not attempt to isolate these influences. Our goal in this study is to estimate the differential net effects of individual, family and community variables (including climate variables on village of origin) on observed migration outcomes. The influence of a particular variable may be different for different migrant destinations, reflecting in part the differential returns to human capital and contextual situations, which included significant changes on climate variables.

The vectors ZF_i , ZH_i and ZC_i are the components of Z_i in Equation (2). In this context, the probability of individual i choosing state j can be described as:

$$P(y_i = j) = P(U_{ij} > U_{il})$$

$$= P[(V_{ij} + \varepsilon_{ij}) > (V_{il} + \varepsilon_{il})]$$

$$= P[(\varepsilon_{il} - \varepsilon_{ij}) > (V_{ij} - V_{il})] \text{ for all } j \neq l$$

Following Hausman and McFadden (1984), if and only if ε_{ij} are independent and identically distributed (iid) with the Weibull distribution, we obtain the familiar multinomial logit model (we have to notice that if $J = 2$, the multinomial logit model represents a model with two discrete outcomes, that means a simple logit model), in which individual i is paired with migration status j such that $U_{ij} \geq U_{il}$ for all $l \in \{ 0, 1, ... J \}$, where J is the total number of migration status. The probability that individual i is paired with regime j can be represented by the next equation:

$$prob(U_{ij}) > U_{il} ,\ \forall j \neq l) = \frac{e^{\beta Z_{ij}}}{\sum_{l=0}^{J} e^{\beta Z_i}} \qquad (4)$$

where Z_{ij} represents all the observed factors or explanatory variables and β represents parameters obtained from the model. The parameters of this model are estimated using the maximum likelihood algorithm in Stata (Long and Freese, 2006).

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Appendix C: Emissions Scenarios and Climate Models

Emissions Scenarios

According to the Intergovernmental Panel on Climate Change (IPCC), a 'scenario' is a coherent, consistent description of how the climate system of our planet may develop in future.[1]

Future greenhouse gas (GHG) emissions are the product of very complex dynamic systems. Levels of GHG emissions are determined by forces such as demographic growth, socio-economic development or technological change. As a result, their future evolution is highly uncertain. Scenarios can be seen as alternative images of how the future might unfold. They are useful in climate change analysis, in assessing impact and in initiatives to adapt to and mitigate effects.

In 2000 the IPCC completed its Special Report on Emissions Scenarios (SRES). These scenarios address the period from 1990 to 2100 and include various assumptions on socio-economic factors such as global population and gross domestic product. The SRES scenarios have been used as the basis for climate projections in Atmospheric General Circulation Models (AGCMs) and coupled ocean-atmosphere models.

Four different narrative storylines were developed to consistently describe the relationships between emission driving forces and their evolution and add context for the scenario quantification. Each storyline represents different demographic, social, economic, technological and environmental changes (or trends), which may be viewed positively by some people and negatively by others. The scenarios cover a wide range of the main demographic, economic and technological driving forces of GHG and sulphur dioxide emissions and are representative of the literature. Each scenario represents a specific quantitative interpretation of one of four storylines. All the scenarios based on the same storyline constitute a scenario 'family', whose characteristics and types are described below.[2]

A1

The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. The key issues are inter-regional cultural and social interaction and capacity building, with a substantial reduction in regional differences in per capita income. The A1 scenario family is divided into three groups that describe alternative directions of technology change in the energy system. The three

A1 groups are distinguished by their technological emphasis: fossil-intensive (A1F1), non-fossil energy sources (A1T) or a balance across all sources (A1B).

A2

The A2 storyline and scenario family describes a very heterogeneous world. Its key distinguishing characteristics are self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change is fragmented and slower than in other storylines.

B1

The B1 storyline and scenario family describes a convergent world with the same global population, which peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures towards a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis in this storyline is on global solutions to economic, social and environmental sustainability, including improved equity.

B2

The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than in the A2 storyline, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

Climate Models

UKMO-HadGEM1Coupled model – Hadley Centre Global Environmental Model, version 1: (‘HadGEM1’)

HadGEM1 is a coupled climate model developed at the UK’s Met Office Hadley Centre for Climate Prediction and Research, used in the IPCC’s Fourth Assessment Report. This model represents a significant advance on its predecessor, the HadCM3 model, used in the IPCC’s Third Assessment Report.

The atmospheric component of HadGEM1 differs markedly from that used in HadAM3. The benefits of the new model include: a non-hydrostatic, fully compressible atmosphere formulation with very few approximations to the basic equations; semi-Lagrangian advection for almost all prognostic variables (except density), permitting relatively long time steps to be used at high resolution; a conservative and monotone treatment of tracer transport; better geostrophic adjustment properties. Another key feature is the inclusion of the interactive modelling of aerosols, driven by surface and elevated emissions (from both natural and anthropogenic sources).[3] The standard atmospheric component uses a resolution of 1.25° x 1.875° in latitude and longitude, which produces a global grid of 192 x 145 cells. This resolution is equivalent to a surface resolution of about 208 km x 139 km at the equator, reducing to about 120 km x 139 km at 55 degrees of latitude. The vertical resolution uses thirty-eight layers extending to over 39 km in height. The atmospheric component of the model also includes land surface processes (such as seasonal vegetation) and runoff from rivers.

The ocean component of HadGEM1 is based on the Bryan-Cox code[4] and was developed from the ocean component of HadCM3[5]. The model uses a latitude-longitude grid with a zonal resolution of 1° and meridional resolution of 1° between the poles and 30° latitude. From 30° to the equator the meridional resolution increases smoothly to 1/3°, giving 360 X 216 grid points in total. It has forty unevenly spaced levels in the vertical, and uses higher resolution near the surface for better resolution of the mixed layer and the thermocline. For more information, see Johns *et al*. (2006)[6].

MIROC 3.2-HIRES
The high-resolution MIROC 3.2 Hires, developed at the Japanese National Institute for Environmental Studies, has the highest resolution of all the models used in the IPCC's Fourth Assessment Report. Its main features are described below.

Atmospheric component: The model basically uses a leap-frog scheme for temporal integration of equations. In the high-resolution version, the horizontal resolution is approximately equivalent to a grid (longitude-latitude) of 1.125°. The vertical resolution uses fifty-six vertical sigma layers, with finer vertical resolution in the planetary boundary layer and around the tropopause. In the medium-resolution version, the horizontal resolution is approximately 2.8125°. The vertical resolution uses twenty vertical sigma layers with finer vertical resolution in the planetary boundary layer.

Land surface-atmosphere interface: The model used to simulate processes at the land surface-atmosphere interface is the MATSIRO (Minimal Advanced Treatments of Surface Interaction and RunOff), which is described in detail in Takata et al. (2003)[7]. The model has the following general features. MATSIRO represents energy and water exchange between land surface and atmosphere. MATSIRO receives temperature, specific humidity, wind speed and pressure of the lowest atmospheric level, and precipitation and downward short-wave and long-wave radiation flux from the atmospheric model. MATSIRO uses this data to calculate and provide turbulent fluxes of momentum, latent and sensible heat and upward short-wave and long-wave radiation fluxes to the atmospheric model. It also calculates runoff. The prognostic variables of MATSIRO are: canopy temperature and surface temperature of snow-free and snow-covered areas, canopy water content, snow amount, snow temperature, snow albedo, soil temperature, soil moisture content, and frozen soil moisture content.

Ocean component: In the high-resolution version of the model the resolution is 0.28125° zonally and 0.1875° meridionally; there are forty-seven vertical levels. The zonal resolution of the medium-resolution version is 1.4° and the meridional resolution is from 0.5° to 1.4°; there are forty-three vertical levels. Free-surface or rigid-lid is used and the salinity boundary condition is a virtual salt flux or water flux.

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