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The Effect of Hydro-Meteorological Emergencies on Internal Migration

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Summary. — We estimate the effect of hydro-meteorological emergencies on internal migration in Costa Rica during 1995–2000. We find that, on average, emergencies significantly increase average migration. However, we also find that emergencies with the most severe consequences, those with loss of lives, decrease migration. The severity of the consequences may explain the differences in the sign of the effect in previous research. We also find that emergencies significantly increase population in metropolitan areas. Less severe emergencies significantly increase migration toward metropolitan areas. More severe emergencies significantly decrease migration toward non-metropolitan areas.

Key words — migration, emergencies, natural disasters, climate, Latin America, Costa Rica

1. INTRODUCTION

An increasing body of evidence suggests that climatic systems are changing around the world (IPCC, 2007, 2012). There are also indications that, along with rising temperatures, the occurrence and intensity of extreme meteorological events may rise (UNDP, 2012). As a consequence, policy makers and researchers have increasingly focused their attention on understanding how weather shocks will affect human wellbeing. Migration is one commonly used variable in economic models that reflect how climate and weather affect quality of life (see, for instance, Piguet and Laczko, 2014; McLeman and Brown, 2011; Cebula and Alexander, 2006; Graves, 1980).

The relationship between extreme climatic events and migration has been studied extensively. Extreme hydro-meteorological events could increase migration flows. A household, for instance, might decide to send away one or more of its members to offset the effect of binding market imperfections and reduce idiosyncratic risks (Massey, 1990; Massey *et al.*, 1993; Stark, 1991; Stark and Bloom, 1985; Waddington and Sabates-Wheeler, 2003). Migration could also serve as an adaptation strategy for entire populations in the face of varying climatic conditions (D'Andrea *et al.*, 2011; Petersen, 1958). However, climatic shocks could also lead to reductions in migration flows (Tse, 2011). This, for instance, might be a consequence of the effects that extreme climatic events have on household wealth, increasing migration barriers.

To contribute to this debate, we analyze the effect of hydro-meteorological emergencies on internal migration in Costa Rica during 1995–2000. We run regressions on inter-cantonal migration gross rates. By focusing on gross rates, we are able to determine whether both sending and receiving flows between canton pairs can be affected by the occurrence of hydro-meteorological emergencies, information that would otherwise be ignored by using net rates. Also, by using rates, we can control for the "gravity effect" that population size has on migration flows both at origin and destination. Namely, we run regressions nationwide, but we also split the sample between those inside and outside the San José Metropolitan Area (also known as the Great Metropolitan Area), where Costa Rica's largest and most urbanized area lies.

We use generalized linear models (GLM), following Papke and Wooldridge (1996) for models where the dependent variable varies from 0 to 1. Our results show that an increase of one hydro-meteorological emergency in the canton of origin increases migration rates, on average, between 0.08 and 0.11 percentage points of the total population of the canton of origin, after controlling for socioeconomic and demographic variables of both origin and destination. These results are always significant and robust to different specifications. We also test ordinary least squares and find that the effects are even higher (0.34 increase in migration rate).

We further break down the data to test whether different types of emergencies affect migration similarly. We split emergencies by type, and analyze the separate effect of floods, landslides, and other events to assess the effect of each component on migration. Our findings suggest that there are differentiated effects by type of event, although the sign of the effect is either positive or insignificant.

We also split emergencies by the consequences they had on populations. We analyze separately the effect of emergencies with loss of lives and other emergencies, which we define as less severe emergencies. We find that less severe emergencies, which were the most numerous, fostered emigration from affected areas. However, we also find that emergencies with loss of lives had a negative impact on migration. The severity of the consequences of the event may explain the different signs found in previous research.

Additionally, we analyze how the effects of hydro-meteorological emergencies might change when we focus on migration

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into the San José Metropolitan Area. We find that, within non-metropolitan areas, hydro-meteorological emergencies increase migration, especially to metropolitan cantons. Within metropolitan areas, these events also increase migration, especially to other metropolitan cantons. We also analyze these effects by severity by making the aforementioned partition of emergencies with loss of lives and less severe emergencies. We find that less severe emergencies significantly increase migration toward the San José Metropolitan Area. However, the most severe emergencies (those causing loss of lives) significantly decrease only migration toward non-metropolitan cantons. This set of results implies that emergencies, even if they do not directly affect urban areas, will significantly and positively affect urban population. This issue is especially important in developing countries, where cities are already facing problems associated with overpopulation, such as congestion and housing deficits (Lora, 2010; UNFPA, 2011).

The remainder of this paper is organized as follows: Section 2 discusses literature on migration and its link to changing climatic conditions. Section 3 describes the model specification and dataset. Section 4 presents results and Section 5 concludes.

2. BACKGROUND

(a) *Weather events and emergencies*

Central America is particularly prone to experiencing major weather events (see for instance Magrin *et al.*, 2014; Palmieri *et al.*, 2006; Pielke *et al.*, 2003; Tucker *et al.*, 2010). Moreover, tropical cyclones forming in the Atlantic, which are the most recurrent type of major weather event to hit the region, have been increasing steadily since 1970 (NOAA, 2012). The number of major hurricanes has also been growing, at even faster rates, accounting for nearly 14% of all cyclones in the 2000–09 decade, in contrast to the 10% they represented during 1970–79 (NOAA, 2012). Current forecasts by the IPCC predict an increase of 10% in the number of major meteorological events faced by the region in the next three decades (ECLAC *et al.*, 2011).

In Costa Rica, 40 out of the 44 national emergencies to which the Costa Rican National Emergencies Commission responded during 1993–2009 were related to extreme weather episodes, striking rural areas the most. Most important, a large number of smaller weather-related occurrences repeatedly hit the country. Costa Rican authorities report that they responded to 23 national weather-related emergencies during 2000–09, but nearly 5000 minor events during the same period.

Some climate change scenarios have suggested that by 2040 the country may have an intensification of seasons on the Pacific shore and in the Central Region (where 60% of the population live). The Atlantic and North regions, which are already subject to intense rainfall seasons, may also experience a sharp increase in rainfall levels in the wet season. Additionally, the country may face more droughts, water scarcity, and floods as a result of climate change (UNDP, 2012).

(b) *Climate, climate change, and migration*

Climate changes have greatly contributed to shaping today's population distribution across the globe (Meze-Hausken, 2000). Higher temperatures, sea-level rise, and changes in precipitation levels, variability, and intensity may lead to climate-related migration (Foresight, 2011). Migration can be fostered by negative agricultural productivity shocks and labor demand decline, which are very likely to be affected by climate phenomena; also, climate shocks may lead to loss and damage of infrastructure, resulting in net wealth loses (Marchiori *et al.*, 2011). These two channels suggest the rural poor will be affected the most (Piguet *et al.*, 2011).

Analysis of the current contribution of climate to migration poses challenges. First, existing studies are unevenly distributed and mostly focused on certain regions (Piguet and Kaenzig, 2014). Secondly, studies that have analyzed the relationship between migration and climate change have not been properly validated and estimates are often full of best guesses (McLeman, 2011; Oliver-Smith, 2008). For instance, existing estimates of migrants after Ethiopia's drought during the 1980s range from 116,000 to 1.32 million (Meze-Hausken, 2000). Third, the environment may play only a contextual role in the decision of when and whether to migrate rather than being a direct cause of migration flows between regions, so that identifying causation may be elusive (IOM, 2009; OCHA-IDMC, 2009).

In recent years, an increasing body of evidence has analyzed climate change effects on migration decisions at the community level. For example, evidence from Greenland in the past 4500 years shows that abrupt temperature changes in the course of a few decades coincided in timing with settlement and abandonment by local cultures (D'Andrea *et al.*, 2011). Additionally, it has been documented that high climate variability was associated with the migration period between 250 and 550 C.E. in Europe (Büntgen *et al.*, 2011). Increases in the frequency and intensity of hydro-climatic hazards is projected in Europe, with important implications for patterns of migration (Mulligan *et al.*, 2014). The natural catastrophes associated with the presence of climate variability and extreme events will also play an important part affecting migration patterns in Latin America (Kaenzig and Piguet, 2014).

(c) *Weather variability and migration*

When facing climate shock risks and events, one alternative response or adaptation is migrating out of the affected area. Out-migration as a response to extreme hydro-meteorological events can be rationalized in two different ways. One is a household decision where one individual is sent off. Another is a group movement, where entire households and even communities migrate.

Neoclassic migration theory has stressed the importance of distance costs and economic expectations as the core factors driving migration decisions (Sjaastad, 1962; Todaro, 1970; Todaro and Harris, 1970). However, the new economics of labor migration models emphasizes the role of migration as a risk reduction strategy, where households decide to send away one or more of their members to offset the effect of binding market imperfections and reduce idiosyncratic risks (Massey, 1990; Massey *et al.*, 1993; Stark, 1991; Stark and Bloom, 1985; Waddington and Sabates-Wheeler, 2003). For example, the lack of an insurance market instrument to offset the potential effects of extreme weather events increases the risks associated with rain-fed agriculture (Clarke and Grenham, 2011). If one or more household members migrate, households may then offset the idiosyncratic risks associated with extreme weather events and other location-specific characteristics, thereby reducing overall risk.

Empirically, estimations of weather-induced migration have looked for a methodological solution to overcome the challenges of estimating causal effects [1] in the migration literature (Munshi (2003) for Mexico; Chen (2009) for China; Pugatch and Yang (2010) for Mexico). These papers used rainfall variability as an instrumental variable for migrant flows in rural areas, which would in turn cause changes in an outcome variable of interest. Migration processes were thus conceived as a response to declining agricultural yields as a result of adverse weather conditions in the community of origin, which in turn reduced income and employment levels for rural households. This view considers migration as a second order outcome of weather shocks. Migration is therefore seen as an adaptive response to impaired living conditions due to weather shocks. Results from several large quantitative studies are consistent with this view, suggesting that weather shocks affect agricultural production, thus producing labor surpluses (shortages) at the origin, which would in turn promote (deter) migration flows (Feng *et al.* (2010)[2] for Mexico; Feng *et al.* (2012) for the United States; and Nguyen *et al.* (2013) for Vietnam). Droughts, for instance, affected mainly men's labor migration in rural Ethiopia (Gray and Mueller, 2012a). Additionally, weather anomalies have been found to reduce post-shock consumption levels (a metric for increased vulnerability), resulting in a higher propensity to migrate (Vicarelli, 2011).

(d) *Climate-related emergencies and migration*

Empirical research looking at the effects of floods on migration has significantly increased in the last years (see, for instance, Tse, 2011; Saldaña-Zorrilla and Sandberg, 2009; Gray and Mueller, 2012b; Nguyen *et al.*, 2013). However, the effects found in previous work have shown different signs and levels of significance. For instance, using an individual panel dataset to estimate the effect of floods on household migration decisions across provinces, districts and sub-districts in Indonesia, Tse (2011) finds that floods actually reduce the likelihood for households to move out at any geographical level, while Joseph *et al.* (2011) argue that there will be limited effects, albeit positive, of weather in internal migration in Yemen.

Additionally, Tse (2011) outlined the theoretic channels by which weather-related emergencies may both decrease emigration and increase immigration into affected areas. For instance, damaged infrastructure may result in an increased demand for workers, resulting in an increase in the marginal product of labor in the construction sector. The marginal product of labor can also be increased by the effects of extreme weather events on soil fertility. In particular, soil fertility can be enriched by alluvial deposits in floods (Tse, 2011). Additionally, extreme weather events can result in a greater mobilization of government, national, and international agencies in order to provide help and support. This was the case in Nova Friburgo, Brazil, where post-flood investments included reconstruction tasks, tax rebates, subsidies, and credit lines (Capellini *et al.*, 2010). The increase in the marginal product of labor results in increased employment opportunities, and therefore generates a greater incentive to migrate into affected areas.

The existence of social networks and social ties may also result in an increase in immigration. Although social networks and family ties have been identified as a predominant mechanism for emigration from disadvantaged regions (see, for instance, Massey, 1990), the existence of social ties in the face of extreme weather events can also generate flows into affected areas. This immigration can take place for the purpose of participating in reconstruction tasks and providing support to affected families. Also, property rights may be at risk of harm from post-shock isolation, resulting in a greater incentive for families to protect their landholdings (Tse, 2011).

Extreme weather events can change wealth levels, affecting the capacity of households to pay for migration-related costs. Wealth levels can change if extreme events damage or destroy assets such as housing or land holdings, or if extreme events induce a reduction of income. For instance, although not strictly related to climate, Halliday (2006) found strong earthquakes are associated with sharp decreases in migration, suggesting the severity of the event may act as a barrier to exit. Although Tse (2011) outlines the mechanisms by which disasters can act as deterrents to migration, he does not find any of these mechanisms to be significant. In particular, he finds that disasters do not affect land holdings, housing, financial assets, farm business assets, or non-farm business assets in Indonesia, ruling out some of the wealth channels through which floods may operate.

However, Saldaña-Zorrilla and Sandberg (2009), using a spatial model for Mexico's municipalities where weather events are the predominant source of natural disasters, find that regions more frequently affected by natural disasters show higher migration rates. They also find that marginalized regions, as defined by government agencies, are more prone to migration than non-marginalized regions in the event of natural disasters. They argue that a more educated population, present in non-marginalized municipalities, is better informed about emigration as a coping strategy. Moreover, Gray and Mueller (2012b) find the effects of flooding were primarily non-significant, although, when testing for non-linear effects, they find within-district mobility increased for those whose sub-district was subject to moderate flooding, a result driven mainly by women and poor households. Meanwhile, Maurel and Kubik (2014) suggest that migration out of Tanzania's rural areas is fostered by the reductions in agricultural income resulting from weather shocks. This reduction arises from significant negative impacts on crop production, which in turn affects those households that rely the most on agricultural income.

Additionally, Hurricane Mitch, for instance, caused a sharp migration movement especially to North America; migration rates from Honduras and Nicaragua increased up to 300% and 40% respectively in the months after the hurricane (FAO, 2001), while Escobar (2006) and Alscher (2010) also found large migrations out of Chiapas after Mitch hit the region. However, short distance movements may be more relevant, as Vicarelli (2011) finds that individuals and households may only move far enough to avoid the natural phenomena that affected them in their current area.

Vicarelli (2011) also finds that those who received government cash transfers or who lived in beneficiary regions (but who did not receive cash transfers themselves) were more likely to migrate out of affected areas, a result that suggests that the presence of safety nets may loosen financial constraints and favor migration. This result is consistent with Drabo and Mbaye (2011), who find that natural disasters foster international migration for those whose educational achievement is the highest.

3. DATA

Migration information was collected from the 2000 census implemented in July that includes Costa Rica's 81 cantons. We use inter-cantonal gross migration rates in the five year period during 1995–2000. Migration rates between the canton of origin and destination are calculated as the proportion of people living in the canton of destination in 2000 who lived in the canton of origin in 1995, relative to the canton of origin's total population in 1995. We estimate the number of people living in the canton of origin in 1995 by summing up movers and non-movers. The share of migrants relative to the total population in 1995 is defined as the gross migration rate (see, for instance, Fields, 1982; Wadycki, 1974). These flows represent a total of 6480 observations, 81 X 80 pair of cantons, thus excluding within-canton movers and non-movers.

To construct the hydro-meteorological events variable, reports of damage from Costa Rica's DesInventar Database (DesInventar, 2009) on storms, electric storms, flash floods, floods, rainfall, strong winds, and weather-related landslides between July 1995 and June 2000 are counted by canton (Figure 1). DesInventar compiles information on natural disasters grouped by type, geographic area of occurrence, reporting source, and reported damages in Costa Rica. We focus on the data available from the National Emergencies Commission (CNE), which started reporting in 1995. Having the same data source across time provides more reliability. The year 1995 also marks the starting point of migration decisions in our dataset.

Methodologically, DesInventar counts a natural disaster as an event causing an effect on human lives or economic infrastructure, with no particular lower bound on the size of the damage caused. Additionally, it counts as one event the effect on a minimal geographic unit (namely, a neighborhood) so that a disaster that created extensive damage is counted as a number of events equal to the number of neighborhoods affected. Because our data are at the canton level, this serves as a unique opportunity to measure the frequency, type, impacts, and extensiveness with which a particular canton has been subject to extreme weather events. Table 1 shows the types of emergencies we used in the analysis and how they were distributed over time and between non-metropolitan and metropolitan cantons.[3] The total number of emergencies is the lowest in the period 1997–98[4] and the highest in 1999–2000. In our sample, we focus on two subsets of emergencies. One splits emergencies by type, into floods, landslides, and other emergencies. The other splits emergencies by selecting those with loss of lives.

The DesInventar database records disasters for Costa Rica from 1969 to date. In order to be included in the database, an emergency has to be reported by one of the system's reporting sources. In this respect, DesInventar does not directly monitor the occurrence of emergencies, but rather relies on the reports of other sources that usually serve as monitors of emergencies, such as newspapers and national agencies for disaster attention. However, the reporting source may vary across different periods of time. In the case of Costa Rica, it was not until 1995 that the Costa Rican Agency for Risk Prevention and Emergency Attention (CNE) reported the occurrence of disasters to the DesInventar database, while the source for previous years relied on newspaper reports. Because of this, reported events during 1990–95 are not comparable to those reported during 1995–2000. Given this situation, we construct a variable that considers reported emergencies by canton during 1990–95, using *La Nación* and *La República* as the sources of reported events. Both newspapers had at the time nationwide coverage and a focus on general news.

The rest of the explanatory variables are at the canton level and correspond to the base period 1995 (unless specified otherwise); they are grouped into nine categories (see Table 2): (i) health: child mortality rate; (ii) education: quality of classrooms and enrollment rates; (iii) economic: employment growth, measured as the rate of change in the number of employees contributing to social security; average residential power consumption, as a proxy for income; average industrial power consumption to account for industrial activity; and the 1984 marginalization index,[5] which measures the access to basic services by canton; (iv) security: reported homicide rate; (v) amenities: reported number of businesses per capita in the leisure and hotel-and-restaurants sectors in the 1990 business census; (vi) political: abstention rate in the 1994 presidential elections; (vii) demographic variables: age composition, urban and rural population five years or older in 1984; (viii) location: two sets of dummy variables to account for region of origin and region of destination, a distance variable with distance between each canton's capital, and a third variable to indicate whether cantons are adjacent; and (ix) climatic: average

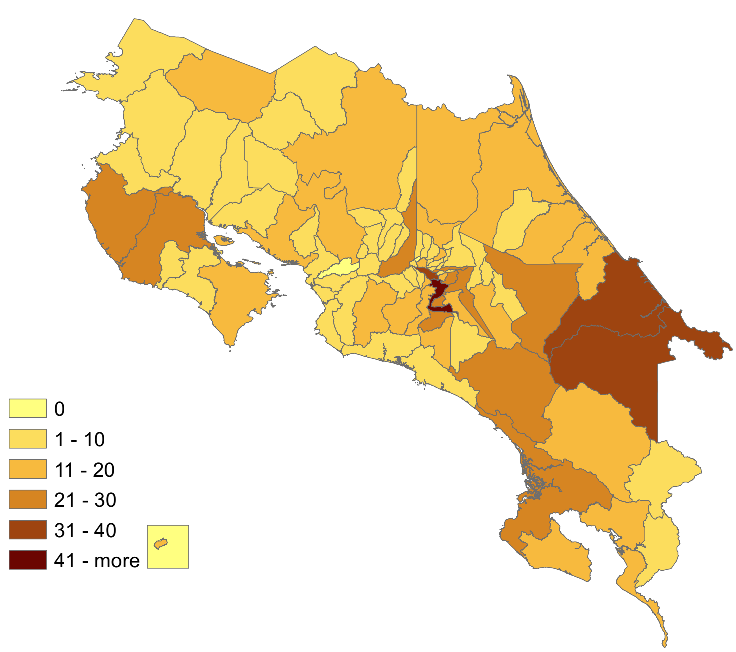

Figure 1. *Hydro-meteorological emergencies.*

Table 1. *Hydro-meteorological emergencies 1995–2000*[a]

Period[a]	1995–96		1996–97		1997–98		1998–99		1999–2000	
	SJM	No SJM	SJM	No SJM	SJM	No SJM	SJM	No SJM	SJM	No SJM
Total emergencies	11	69	4	104	14	16	65	109	298	200
By type										
Landslides	3	2	2	36	3	1	20	26	106	53
Floods	8	66	2	67	7	15	43	82	170	141
Gales	0	0	0	1	2	0	2	0	8	3
Flash floods	0	1	0	0	2	0	0	1	2	2
Rain	0	0	0	0	0	0	0	0	12	1
By impact										
Emergencies with lossof lives	0	4	1	13	1	0	0	1	0	1
Emer. with damaged houses[b]	6	6	0	48	10	11	52	61	240	131
Other emergencies	5	59	3	43	3	5	13	47	58	68

[a] From July 1995 to June 2000. SJM. San José Metropolitan area.
[b] Damaged houses exclude those emergencies also having loss of lives.

monthly precipitation levels and annual mean temperatures were incorporated.

4. EMPIRICAL STRATEGY

(a) *Specification*

We use a gravity model to explain cross-canton gross migration rates [6] as a function of population, distance between the cantons and a set of push and pull factors [7] that influence in and out-migration decisions. Considering all these factors, individuals rationally weigh up the costs and benefits of migrating. Individuals will migrate if and only if the benefits from migrating are higher than the monetary, psychological, information and opportunity costs of doing so. Migration rates are explained as an outcome of a set of push and pull factors that refer to location-specific characteristics that may affect migration decisions. [8]

According to this, our econometric model takes the following form:

$$m_{ij} = \beta_1 HE_i + \beta_2 d_{ij} + \beta_3 adj_{ij} + \sum_{k=1}^{K} \alpha_k X_{ik} + \sum_{l=1}^{L} \delta_l (Z_{jl} - Z_{il}) + \lambda_{IJ} + u_{ij},$$

where m_{ij} is the migration rate from location i to location j, HE_i is the number of hydro-meteorological events in location i, d_{ij} is the distance from canton i's capital to canton j's capital, and adj_{ij} takes the value of 1 if cantons i and j are adjacent and 0 otherwise. We additionally control for K characteristics of location i, X_{ik}, for the differences of L characteristics between j and i, $Z_{jl} - Z_{il}$, and for constant migration flows, λ_{IJ}, between region I where canton i is located and region J where canton j is located, which do not depend on the other variables of the model.

We expect that geographical proximity will increase migration flows. This implies that we expect that β_2 will be negative and β_3 will be positive. Additionally, we expect that regions that are closely linked to each other will also have higher migration flows. This implies that the higher the economic and geographical proximity between region I and region J, the higher will be λ_{IJ}. We also control for characteristics of the canton of origin, X_{ik}. These include demographic and climatic variables (see Table 2). The expected signs for these variables are ambiguous. However, these are key control variables as they explain migration flows and might be correlated with emergency episodes. Finally, we also control for differences in the socioeconomic characteristics of destination and origin (see Table 2). We expect that people will migrate toward cantons with lower child mortality, a lower marginalization index, lower homicide rates, and lower abstentionism relative to the canton of origin. This implies that we expect negative coefficients for these variables. We also expect that migration will increase toward cantons with higher quality of class rooms, higher enrollment rates, higher employment growth, and higher power consumption relative to the canton of origin. This implies that we expect positive coefficients for these variables.

Given that m_{ij} is a proportion that can only take values between 0 and 1, we use a generalized linear model (GLM) following Papke and Wooldridge (1996). The generalized linear model addresses the bounded nature of our dependent variable. This is an important methodological contribution as previous papers have used linear models (see for instance Feng *et al.*, 2010 and Saldaña-Zorrilla and Sandberg, 2009). However, we also run ordinary least squares (OLS) for our core model in order to compare the results between GLM and a linear specification. Note that the coefficients associated with Papke and Wooldridge's (1996) GLM are not marginal effects. Marginal effects of a hydro-meteorological event on migration must be calculated conditioned on some value of the vector of explanatory variables. In this paper, we report marginal effects for GLM models that were calculated at the sample's mean for each independent variable.

(b) *Identification*

In order to estimate unbiased effects of hydro-meteorological emergencies on internal migration, the correlation between the error, u_{ij}, and the presence of emergencies, HE_i, should be zero. This condition could be violated if there are unobservable factors that are simultaneously correlated with the presence of emergencies and migration. For instance, it might be the case that emergencies are correlated with historical average temperature and precipitation levels and therefore with agricultural productivity, which might also affect migration flows. If this is the case, the estimated effects of emergencies might be biased upward. To address this issue, in our regression, we control for population, historical average temperature, and precipitation levels, among other variables.

Certainly, it is highly unlikely that migration would affect the likelihood of a hydro-meteorological event. However,

Table 2. *Descriptive statistics*

Variables	All		SJM	No SJM	Period	Source
	Average	Stand. error	Average	Average		
Dependent variable						
Gross migration (%)[a]	0.13	0.00	0.13	0.13	1995–2000	INEC
Variable of interest						
Hydro-meteorological emergencies	10.98	0.13	12.65	9.96	1995–2000	CNE
Emergencies with loss of lives	0.26	0.01	0.06	0.38	1995–2000	CNE
Less severe emergencies	10.73	0.13	12.58	9.58	1995–2000	CNE
Floods	7.42	0.09	7.42	7.42	1995–2000	CNE
Landslides	3.11	0.06	4.32	2.36	1995–2000	CNE
Other types of emergencies	0.46	0.01	0.90	0.18	1995–2000	CNE
Control Variables						
Socioeconomic						
Child mortality (per 1000 births)	13.1	0.5	12.21	13.6	1995	Salud
Classrooms in good condition (%)	71.6	1.2	80.4	65.8	1995	MEP
School enrollment (%)[b]	59.0	1.3	63.1	56.4	1995	MEP
Growth of employees in social security	0.04	0.00	0.06	0.03	1987–95	CCSS
Residential power consumption (KWts)	2.4	0.1	3.0	2.0	1995	ICE
Industrial power consumption (tens of MWts)	1.6	0.4	2.8	0.9	1995	ICE
Social marginalization index	5.5	0.3	3.3	6.9	1984	INEC
Homicides (per 1000 people)	4.6	0.8	3.2	5.4	1995	OIJ
Restaurant and Hotel Services (per 1000)	2.9	0.2	2.0	3.4	1990	INEC
1994 Abstentionism (%)	17.8	0.5	16.7	18.5	1994	TSE
Demographic						
Population size 5 years or older (thousands)	41.1	4.9	57.9	30.6	1995	INEC
Population aged less than 20 (%)	49.6	0.5	46.2	51.7	1984	INEC
Population between 20 and 29 (%)	19.1	0.2	20.2	18.4	1984	INEC
Population between 30 and 39 (%)	11.9	0.1	13.1	11.2	1984	INEC
Population between 40 and 49 (%)	7.6	0.1	8.0	7.4	1984	INEC
Population between 50 and 64 (%)	7.4	0.1	7.9	7.1	1984	INEC
Population aged 65 or more (%)	4.3	0.1	4.6	4.1	1984	INEC
Urban Population (%)	31.0	2.7	47.8	20.5	1984	INEC
Geographic						
Neighboring cantons dummy	0.06	0.00	0.06	0.06	1995–2000	IGN
Distance between canton capitals (tens of km)	15.7	0.1	12.4	17.7	1995–2000	MOPT
Area (Square km.)	630.9	83.5	104.3	957.4	1980	IGN
Climatic						
Average precipitation January[d]	61.5	9.9	32.2	79.6	[c]	IMN
Average precipitation February[d]	46.3	6.9	25.5	59.3	[c]	IMN
Average precipitation March[d]	45.5	5.4	28.2	56.2	[c]	IMN
Average precipitation April[d]	93.2	7.7	72.0	106.3	[c]	IMN
Average precipitation May[d]	289.6	10.9	266.2	304.1	[c]	IMN
Average precipitation June[d]	309.3	9.6	280.2	327.3	[c]	IMN
Average precipitation July[d]	258.4	12.3	201.0	294.0	[c]	IMN
Average precipitation August[d]	315.3	19.4	295.9	327.4	[c]	IMN
Average precipitation September[d]	362.2	12.9	338.9	376.6	[c]	IMN
Average precipitation October[d]	383.0	14.6	344.7	406.7	[c]	IMN
Average precipitation November[d]	214.3	12.1	168.9	242.5	[c]	IMN
Average precipitation December[d]	111.6	13.8	63.0	141.8	[c]	IMN
Mean temperatures (Celsius degrees)	21.8	0.4	18.9	23.5	1950–2000	Clim
Observations	81		40	41		

SJM. San José Metropolitan area. Percentages (%) range from 0 to 100. Rates range from 0 to 1.
[a] Relative to the population of the canton of origin in 1995.
[b] Includes enrollment in primary and secondary school.
[c] The time span varies according to the precipitation station. Observations taken from precipitation stations active for at least 15 years.
[d] Millimeters.

migration could affect what is considered an emergency. For instance, a flood that would have clearly been an emergency in highly populated areas might not have been considered as such in less populated areas. This could potentially affect the independent variable. However, if this is the case, one would expect that migration might lead to a reduced number of emergencies reported. This might bias the coefficients against our hypothesis.

Additionally, given that migration is measured in the same period as emergencies, it could be the case that most of the migration in a canton during the period took place before the floods. If pre-flooding migration flows are similar to those places that are less affected, then one should not expect any source of bias. If migration flows are larger in those cantons that are affected by hydro-meteorological emergencies, the estimates will be biased only if these migration flows were caused by unobservable factors that are not considered in the regression. However, within the regression, we control for several social, economic, climatic, and demographic factors of the cantons of origin and destination.

Other identification challenges appear due to the data. First, an individual might leave the canton after an emergency but come back just before the census. These short-term migration events will not be captured in the analysis. Second, there will also be very short-term migration events that will be captured by the data if an individual leaves just before the census and comes back just after the census. This is certainly a challenge, in that being able to identify and differentiate temporal and permanent migration would be very helpful for policy analysis. However, data with exact dates of migration episodes are very scarce in developing countries and, for the case of Costa Rica, non-existent.

However, to make sure that our results are not simply reflecting effects of emergencies on temporary migration, we run a robustness test. We use as an explanatory variable only emergencies that occur one year before the census. Most of the temporal migration captured by the data will take place for those who left in the last year, as they have not had time to come back. Additionally, short-term migration is usually an immediate remedial reaction to the emergency. So, by eliminating the effects of emergencies in the last year of analysis, we are also partially eliminating the effects over temporal migration episodes.

5. RESULTS

In Table 3, we show regressions testing the effect of emergencies on nationwide gross migration percentages. Overall, we find that an increment of one hydro-meteorological emergency increases nationwide gross migration. GLM estimates shown in columns 1–3 differ from one another in the use of regional fixed effects. Column 1 shows a model with regional fixed effects by origin but not by destination. Column 2 presents a model with fixed effects by region of destination but not by region of origin, while the model in column 3 presents regional fixed effects by both origin and destination. The marginal effect of emergencies on migration is similar across these models. These results suggest that different specifications of regional fixed effects do not significantly affect the estimates.

In column 4 in Table 3, we show the results of an OLS regression using regional fixed effects by both origin and destination. We find that this model also yields positive and significant effects, consistent with the results from the GLM model. However, the coefficient is significantly higher. Our main conclusions will be based on the GLM because it takes into account that our dependent variable is bounded in the closed interval [0,1]. The boundedness of the dependent variable might be what explains the large magnitude of the effect in OLS model. However, it is important to show that qualitatively OLS and GLM yield similar results.

As discussed, the source of data between 1990–95 and 1995–2000 is different. The first period contains only newspaper reports, while the data for the period during 1995–2000 includes only emergencies reported by the Costa Rican disaster response agency. Because of this, we cannot directly test the effects or compare the marginal effects associated with emergencies in each period. However, we can use the emergencies during 1990–95 as controls to assess whether past emergencies, and not current ones, might be the triggers of migration. In column 5 in Table 3, we show the effect of emergencies on migration after controlling for emergencies reported during 1990–95. The marginal effect for emergencies occurring during 1995–2000 is still positive and significant, even after controlling for emergencies during 1990–95, although the magnitude of the effect shows a slight reduction. We will base our conclusions on this model and choose this model to explore further the relationship between emergencies and migration. The marginal effect associated with emergencies in this model is interpreted as follows: an additional emergency in the canton of origin would increase emigration rates to another canton by 0.0010 percentage points of the total population in the canton of origin. Given that there are 80 cantons to which an individual could emigrate, an additional hydro-meteorological emergency causes an aggregate migratory effect of 0.08 percentage points of the total population

Table 3. *Effects of hydro-meteorological emergencies on cross-canton migration between July of 1995 and June of 2000*

Variables Period[a]	(1) 1995–2000 GLM	(2) 1995–2000 GLM	(3) 1995–2000 GLM	(4) 1995–2000 OLS	(5) 1995–2000 GLM	(6) 1995–99 GLM
Between canton pairs	0.0014***	0.0013***	0.0014***	0.0043***	0.0010***	0.0012***
Overall effect in origin[b]	0.11	0.10	0.11	0.34	0.08	0.10
Controls						
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Regional fixed effects by origin	Yes	No	Yes	Yes	Yes	Yes
Regional fixed effects by destination	No	Yes	Yes	Yes	Yes	Yes
Emergencies 90–95	No	No	No	No	Yes	No
Observations	6480	6480	6480	6480	6480	6480

San José Metropolitan area.
*, **, *** represent significance at 10%, 5%, and 1% respectively.
[a] From July 1995 to June 2000.
[b] To obtain the overall effect in the affected cantons, we multiply the estimated coefficient by the number of destinations (80).

in the canton of origin. On average, about 10.4% of a canton's population migrated during that period. This means that one emergency accounts for 0.77% of the total emigration movements in a given canton. These estimates reflect average effects. There might be cantons or sets of cantons where the impacts are significantly larger or smaller.

Given the characteristics of our data, it is not possible to distinguish between permanent and temporary migration. For instance, an individual might leave before June 2000 but return just after July 2000. However, the fraction of individuals who left temporarily and had not come back by June 2000 will be higher for those individuals who left between July 1999 and June 2000, because they have not had enough time to come back, than for those who left at the beginning of the period of study, for instance, in July 1995. To make sure that our results are not simply reflecting effects of emergencies on temporary migration, in Column 6 in Table 4, we show a GLM model that includes emergencies only from July 1995 to June 1999 as the explanatory variable. Despite the fact that we eliminate from the explanatory variable a significant number of emergencies that occurred between July 1999 and June 2000 (see Table 1), we find that emergencies still have a positive and significant effect on migration and that the effect is similar in magnitude to the regression that includes emergencies between July 1995 and June 2000.

Results shown in Table 3 are consistent with previous findings showing that disasters and emergencies can foster migration out of affected areas. Also, the marginal effects found are robust across different specifications. We next proceed to split our sample to analyze the effect of different types of emergencies on migration and to test whether the effects change in the San José Metropolitan Area and in non-metropolitan cantons.

(a) *By type of emergency*

We further break down the data to test whether different types of emergencies affect migration similarly (see Table 4). We split emergencies by type, and separately analyze the effect of floods, landslides, and the other events to assess the effect of each component on migration. More than 90% of our sample consists of emergencies triggered by floods or landslides. We find that all emergencies appear to have an enhancing effect on migration movements for the period 1995–2000. However, the estimated effects are statistically insignificant for the period during 1995–99. This might be explained by the large reduction of emergency occurrences when dropping the last year of analysis (see Table 1). It is important to note that there is only one negative estimate that is statistically insignificant across the periods and types of emergencies considered.

(b) *By consequences of the emergency*

We also split emergencies by the consequences they had on populations (see Table 4). We separately analyze the effects of emergencies with loss of lives and less severe emergencies. We find that the effect of emergencies changes across different types of consequences. For the period during 1995–99 and from 1995 to 2000, the effect of emergencies with loss of lives on migration was negative and significant, a result that suggests that the severity of the impact may impede people from migrating. The effect of less severe emergencies is positive.

(c) *Urbanization effects*

In Table 5, we show models disaggregated by zone of origin and destination. We analyze how the effects of hydro-meteorological emergencies might change when we focus on non-metropolitan and metropolitan migration. We find that, within non-metropolitan areas, hydro-meteorological emergencies increase migration, especially to metropolitan areas. Within the San José Metropolitan Area, these events also increase migration, especially to other metropolitan areas. When we analyze these effects by severity, we find again that less severe emergencies significantly increase migration toward metropolitan areas. However, emergencies with loss of lives significantly decrease only migration toward non-metropolitan areas. This set of results implies that emergencies, even if they are not directly affecting metropolitan areas, will significantly and positively affect population levels.

6. CONCLUSIONS

We estimated the effect of hydro-meteorological emergencies on internal migration in Costa Rica during 1995–2000. We used generalized linear models (GLM) following Papke and Wooldridge (1996) for models where the dependent variable varies from 0 to 1. Our results showed that an increase of one hydro-meteorological emergency at the canton of origin increases migration rates, on average, between 0.08 and 0.11

Table 4. *Effect of emergencies on cross-canton migration between July 1995 and June 2000 by consequences and by type of emergency. GLM marginal effect evaluated at the mean of each sample*

Period[a]	(1) 1995–2000	(2) 1995–99		(3) 1995–2000	(4) 1995–99
By type			By consequence		
Floods	0.0006*	0.0000	Loss of lives	−0.0096***	−0.0094***
Landslides	0.0013***	0.0012	Less severe emergencies	0.0010***	0.0006
Other emergencies	0.0045*	−0.0017			
Controls					
Control variables	Yes	Yes		Yes	Yes
Fixed effects by origin	Yes	Yes		Yes	Yes
Fixed effects by destination	Yes	Yes		Yes	Yes
Emergencies 90–95	Yes	Yes		Yes	Yes
Observations	6480	6480		6480	6480

SJM. San José Metropolitan area.
*, **, *** represent significance at 10%, 5%, and 1% respectively.
[a] From July 1995 to June 2000 for 1995–2000 and from July 1995 to June 1999 for 1995–99.

Table 5. *Effects of hydro-meteorological emergencies on cross-canton migration between July 1995 and June 2000 by zone and by canton's development. GLM Marginal Effects evaluated at the mean of each sample*

Period[a]		1995–2000		1995–1999	
Overall Effect	Origin	Destination		Destination	
		SJM	No SJM	SJM	No SJM
	SJM	0.0015***	0.0003**	0.0058***	0.0008***
	No SJM	0.0018***	0.0000	0.0003	−0.0004
Emergencies split by impact	Origin	1995–2000		1995–1999	
		Destination		Destination	
		SJM	No SJM	SJM	No SJM
Loss of Lives	SJM	0.0278	-0.0077***	−0.0016	−0.0113***
	No SJM	0.0021	-0.0116***	0.0015	−0.0111***
Less severe emergencies	SJM	0.0015***	0.0003***	0.0060***	0.0013***
	No SJM	0.0017***	0.0002	0.0003	0.0000

SJM. San José Metropolitan area *, **, *** represent significance at 10%, 5%, and 1% respectively.
[a] From July 1995 to June 2000 for 1995–2000 and from July 1995 to June 1999 for 1995–1999

percentage points of the canton of origin's total population, after controlling for socioeconomic and demographic variables at both origin and destination. These results are always significant and robust to different specifications.

We also analyzed separately the effect of floods, landslides and other events to assess the effect of each component on migration. Our findings suggested that there are differentiated effects by type of event, although the sign of the effect is either positive or insignificant when it is negative. We then separately analyzed the effect of emergencies with loss of lives and less severe emergencies. We find that less severe emergencies, which were the most numerous, fostered emigration from affected areas. However, we also find that emergencies with loss of lives had a negative impact on migration. A possible explanation of this result is that severe emergencies might reduce wealth and could leave the households without the possibility of covering the fixed costs of migration. In fact, this is consistent with previous empirical results related to earthquakes (Halliday, 2006). The severity of the consequences of the event may explain the different signs found in previous research.

Finally, we analyzed how the effects of hydro-meteorological emergencies might change when we focus on non-metropolitan and metropolitan migration. We find that, within non-metropolitan areas, hydro-meteorological emergencies increase migration, especially to metropolitan areas. Within metropolitan areas, these events also increase migration, especially to other metropolitan areas. Emergencies reinforce migration, especially toward areas that are less economically dependent on agriculture and climate in general. When we analyze these effects by severity, we find again that less severe emergencies significantly increase migration toward metropolitan areas. However, emergencies with loss of lives significantly decrease only migration toward non-metropolitan areas. As discussed previously, reductions in migration as a consequence of severe emergencies can be explained by reductions in wealth and the capacity of covering the fixed costs of migration. These reductions in migration occur especially toward non-metropolitan areas, which are more economically dependent on agriculture and climate-related activities. We conclude that emergencies will lead to increases in metropolitan population. This issue is especially important in developing countries, where cities are already facing problems associated with overpopulation, such as congestion and housing deficits (Lora, 2010; UNFPA, 2011).

Future research should focus on the relationship between climate and hydro-meteorological emergencies. This will help us understand how climate change will affect migration via extreme events and emergencies. Additionally, it would be important to explore the effectiveness of migration as an adaptation strategy. That would test whether those who were exposed to emergencies and migrated ended up better off than those who were exposed to emergencies and did not migrate.

Due to the characteristics of the data, one of the limitations of this analysis was that we could not directly estimate the effects on different types of migration. When better data are available, future research could focus on separately exploring the effects of hydro-meteorological emergencies on short-term and long-term migration. It would also be interesting to test whether the results change when separately considering migration directly linked to emergencies such as evacuation and regular migration decisions. This will also shed light on the mechanisms taking place behind our results.

NOTES

1. These challenges appear when estimating the effects of migration on socioeconomic outcomes because not only does migration affect socioeconomic outcomes, but socioeconomic outcomes affect migration. Additionally, there are numerous unobservable variables that could affect both migration and socioeconomic outcomes.

2. Auffhammer and Vincent (2012) show that the results from Feng *et al.* (2010) are based on a different statistical model than the one stated in the paper. Once the correct statistical model is implemented the results become smaller and statistically insignificant. However, the signs of the effects are the same for both statistical methods.

3. Metropolitan cantons are assigned by the Ministry of Economic Planning.

4. This was the result of the presence of El Niño, which reduced the probability of hurricanes and increases the probability of droughts.

5. We use 1984 as the only available information before 1995. We do this in order to focus on pre-event controls.

6. Using aggregated data to explain migration has been widely used in migration studies. See Piguet (2010), who defines this type of study as "ecological inference based on area characteristics". Some examples include Saldaña-Zorrilla and Sandberg (2009) and Munshi (2003).

7. Push factors incentivize agents to migrate, while pull factors incentivize agents to stay in their cantons of origin. High crime, poverty, and unemployment rates, for instance, in the canton of origin relative to the rates prevalent in other cantons are factors that push agents away from their places of residence. High education levels, incomes, and health indicators in the canton of origin are characteristics that pull agents to stay in their places of residence.

8. For a broader discussion of migration models, see Massey *et al.* (1993), Massey and Espinosa (1997). For a discussion on methodological issues related to migration models and climate, see Piguet (2010) and McLeman (2013).

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