1 Introduction

In recent years, there has been considerable speculation about the possible effects of climate change on migration, especially in developing countries. Stern (2006) noted that 200 million people worldwide live in at-risk coastal flood plains, which would be threatened by changes in sea-level. Moreover climate change may lead to resource scarcity, drought, floods, and other environmental changes that could lead to migration. Marchiori et al. (2012) note that estimates of migration due to environmental factors can vary widely, from 15 million people displaced during the 1970s to 25 million environmental refugees in 1995 alone.

One reason for this disparity is that estimates of migration due to environmental change are often based on the number of people expected to be affected by environmental change (Marchiori et al., 2012). These estimates may not accurately project the number of people who will migrate due to the environmental change, and they may not account for the number of people who would have migrated in absence of the change. Econometric methods can be useful in identifying the portion of migration that can be attributed to environmental change using valid counterfactuals. But while economists have devoted considerable attention to
the study of migration over the past 50 years, they have had relatively little to say regarding the potential effects of environmental change on migration.

In theory, environmental change may cause migration for at least three reasons. First, it may change labor productivity, leading to decreases in labor demand and wages. Individuals may migrate in response to decreased wages (the wage channel). On the other hand, labor demand may rebound through additional investments in capital or adoption of new technologies. Therefore, estimating the migration-response to environmental change requires understanding the degree to which economies respond to changes through migration and the degree to which they adapt through other means. Second, individuals may have direct preferences for environmental factors such as climate. These preferences could lead individuals to migrate in response to adverse climate change (the amenity channel). Third, if individuals are risk averse, environmental change leading to more highly variable wages or income might drive migration toward locations that provide more stable sources of income.

In this paper I will review existing evidence regarding the effects of environmental changes on human migration. In order to motivate the discussion, I will first provide a discussion of economic theory of migration relevant to this literature. The empirical literature regarding environmental factors and migration primarily consists of studies using weather data coupled with aggregate net migration data in order to attempt to identify causal effects of climate changes on migration, and in particular whether migration occurs through the wage or amenity channels. Several of the better studies of this type focus on internal migration within the United States. Rural-urban migration has long been a significant concern in the developing world, and several studies also examine the role climatic factors play in this phenomenon. Finally, the New Economics of Labor migration approach, which emphasizes household-level migration decisions and responses to variation in income,
has led to several studies that examine the effect of weather on household migration decisions. Together, these studies indicate that environmental factors can have significant effects on migration decisions through both the wage and amenity channels. However, there is little evidence that climate change will lead to migration of the scale discussed in the Stern Report. Still, very little is known about migration due to environmental factors within the developing world. More research is needed before conclusions can be reached.

2 Models of migration

2.1 Early models of migration

Early models of migration were primarily descriptive. Although they did not provide formal analysis of factors affecting migration decisions, they provided insights that would be integrated into later more rigorous research (Greenwood, 1993). An early example is that of Ravenstein (1885), who provided a series of stylized facts regarding migration, based on observations of migration within the UK (Greenwood, 1993). The first of these facts—that most migrants move a short distance to nearby major cities—motivated the first wave of formal models of migration. These models, known as gravity models, assume that the relevant factors driving migration flows are the sizes of source and host populations, and the distance between them (Greenwood, 1993). Migration is proportionally related to population sizes within the relevant populations and inversely related to their distance apart. Modified gravity models retained the basic character of gravity models, but also allowed that migration might depend on incomes in each location and other location-specific attributes, potentially including environmental amenities or climate. A weakness of gravity models is that they lacked a strong basis in economic theory.
2.2 Hicks-Sjaastad model

Within economic models of migration, migration is generally viewed as an equilibrating force, which serves to equate marginal wages (or in later models, marginal utilities) across locations. Formal economic models of migration decisions begin with Hicks-Sjaastad model, which treats migration as an investment which increases the productivity of human resource (Sjaastad, 1962). It supposed that individuals migrate across locations when the discounted life-time benefits of living in the new location outweigh the one-time costs of migration. If $w_i$ and $c_i$ represent the wages and costs of living in location $i$, respectively, then an individual will choose to migrate from location $i$ to location $j$ if:

$$\sum_{t=0}^{T} \frac{(w_{jt} - c_{jt}) - (w_{it} - c_{it})}{(1 + r)^t} > C_{ij}$$

where $C_{ij}$ are the costs of migrating from location $i$ to location $j$.

Several important insights follow readily from this model. First, the model suggests that the young will be more likely to migrate than the old, since their discounted stream of benefits from migrating is more likely to outweigh migration costs. Second, if greater distance between $i$ and $j$ implies larger $C_{ij}$, then migration will be more likely between locations that are closer to one another, consistent with Ravenstein’s first law of migration. Third, migration should be increasing in the wage differential between locations and decreasing in the cost differential. Most relevant for this paper, this implies that environmental factors may trigger migration if they result in decreases in expected wages over time in the origin location. Examples might be changes in expected agricultural production due to persistent drought or climate change.
2.3 Todaro model

A subtle revision to this model was introduced by Todaro (1969), who noticed that rural to urban migration is high in developing countries, despite the fact that many of these countries have high levels of unemployment in urban areas. This observation cannot be explained by the Hicks-Sjaastad model, which assumes migration is driven entirely by wage differentials. Therefore, Todaro modifies the model so that migration decisions are a function of expected value of income and cost streams in each location. For example, rural workers may have expectations about how long they will have to wait in order to find a job should they move to an urban location. If the expected wait to find a job is long, then wages will need to be very high relative to the rural wage in order to compensate for the waiting time.

Harris and Todaro (1970) apply this view of migration decisions to an economy with two sectors, urban and rural. The rural sector produces agricultural products following a production function that depends on labor, land, and capital stock. The urban sector produces manufactured goods following a production function that depends on labor and capital stock. Workers in each sector are paid a wage based on their marginal products of labor. Using this model, they argue that minimum wages imposed on the urban sector lead to urban wages that are sufficiently higher than rural wages to induce rural migration despite high levels of urban unemployment. This simple two-sector model has been adapted by several other authors to study other features of rural-urban migration, including the role of climate change (eg. Barrios et al. 2006, Marchiori et al. 2012).

2.4 Equilibrium models

The Hicks-Sjaastad and Todaro models provide simple frameworks through which to view migration, as well as several empirically testable predictions. However, they have failed
to entirely resolve economists’ dissatisfaction, for example, “with the past performance of migration in narrowing geographic income differentials, in spite of the tremendous amount of internal migration taking place in the United States” (Sjaastad, 1962, p. 80). As Borjas (2001) argues, this may because the model ignores the reasons these income differentials exist. If workers base migration decisions not on potential wages across locations, but on the utility they might receive from those wages and from other attributes of the locations, including environmental amenities, it may be possible to observe persistent wage differentials across locations. Models that allow endogenous wage differentials due to amenities and other factors generally assume, in contrast to the Hicks-Sjaastad model, that firms and households locate themselves so that utility is approximately constant across location. These models are sometimes referred to as “equilibrium models,” in which wage differentials persist but utility differentials vanish, to distinguish them from the disequilibrium approach of the Hicks-Sjaastad model, which assumes that wage differences exist because of market disequilibrium (Greenwood, 1993).

Starting from an assumption of equilibrium, it is difficult to explain how migration might occur. Greenwood (1993) argues that within an equilibrium framework, migration can only occur due to non-compensating wage differentials, or wage differentials that do not fully account for differences in the value of regional amenities. Therefore, researchers examining migration from an equilibrium perspective must be sure to account for various climatological, topographic, environmental, and cultural variables that may cause amenity differentials across locations. For the purposes of this review, the equilibrium approach is important because it argues for the purposes of a second channel through which environmental factors can drive migration. Unlike in the Hicks-Sjaastad model, migration in equilibrium models can occur due to direct amenity effects, such as changes in climate or natural disaster risk.
2.5 New economics of labor migration

Departing from the tradition established by the Hicks-Sjaastad model and continued with the Todaro model, New Economics of Labor Migration (NELM) models consider neglected microfoundations of migration decisions, including the role of risk aversion in contributing to migration, the role of credit constraints, behavioral factors, and the implications of viewing the household as a decision-making unit. Stark and Levhari (1982) argue that variation in agricultural income can lead risk averse individuals or households to migrate to urban areas, even absent positive urban-rural wage differentials. Similarly, variation in agricultural income may amplify rural-urban migration. Importantly, NELM models consider that households may be the relevant decision-making unit in migration decisions. Furthermore, household migration strategies may involve alternative migration statuses among household members. Especially in developing countries where unemployment insurance and other social insurance programs are unavailable (Stark and Bloom, 1984, p. 173), family members may migrate in order to spread themselves across sectors in which earnings are negatively correlated. For rural families facing risks of weather anomalies such as drought, this strategy may imply the migration of family members to urban areas, where industry is not subject to the same risks (eg. Stark and Lucas 1988). Alternatively, Rosenzweig and Stark (1989) describe a strategy undertaken by rural Indian households in which marital arrangements provide ties between families distantly located from one another. Distance between families ensures that weather shocks will not be highly correlated across locations. Such strategies allow family members to reduce risk and smooth consumption over time through intrafamily remittance payments. Migration of households members to urban areas or developed countries can also provide families with access to credit markets, which may be relatively undeveloped in the household’s source region. Finally, Stark and Bloom (1984) and Stark and Taylor (1989) also argue for consideration of behavioral factors as drivers of migration.
Individuals or households with low earnings relative to a given reference point may be more likely to migrate than households with high earnings relative to a reference point. This captures the idea that households who are not “keeping up with the Joneses” will be more likely to migrate.

3 Estimates of Effects of Environmental Change on Migration

In this section I first review some of the relevant empirical evidence concerning the effects of climate change on income. Next, I review studies that have directly considered the effects of climate on migration, either through effects of climate on income or through amenity channels. Finally, I review studies that have examined effect of climate on migration in light of NELM models.

3.1 Effects of climate change on migration

A primary dimension along which studies of the effects of climate change on migration vary is the degree to which they are able to identify the causal channel through which climate affects migration decisions. Some studies estimate the direct effect of climate on migration, without respect to the channel through which this effect occurs. These studies may be illustrative, but they generally lack enough insight to provide guidance to policy makers seeking to affect migration. Climate may influence migration through its effects on productivity and wages, or it may have direct effects on migration due to increased amenity differentials between source and host countries. Of the studies that attempt to identify causal channels, some are designed to identify only wage-driven migration, whereas other studies are designed to identify migration due to the amenity channel. I know of only one
study that attempts to simultaneously identify the relative amounts of migration due to each channel.

Barrios et al. (2006) examine the effect of climate change on rural-urban migration in sub-Saharan Africa. Their theoretic model follows Harris and Todaro (1970) in supposing that labor \((N)\) and capital \((K)\) are allocated across two sectors: a rural (agricultural, \(A\)) sector and an urban (manufacturing, \(M\)) sector. Labor is an input in both sectors, but land \(L\), the productivity of which depends on rainfall \((R)\), is an input only in the rural sector, and capital is an input only in the urban sector. In the spirit of the Hicks-Sjaastad model, workers in each sector maximize wage and representative firms within each sector maximize profits. These two conditions cause labor supply within each sector to shift until marginal products of labor are equated across sectors and each is equal to the market wage rate. Because the marginal productivity of workers in the rural sector is dependent on rainfall, this model leads to the hypothesis that decreases in rainfall will drive increases in migration to urban areas.

Barrios et al. (2006) test this hypothesis using aggregate data from 78 developing countries. They regress proportion of urban workers in a country on a series of covariates, rainfall, and country and time fixed effects. They find that decreases in rainfall increase the proportion of urban workers, but the effect is significant only in sub-Saharan Africa. While these results are consistent with their theoretic model, which implies that climate-induced migration is due to declines in agricultural productivity, their econometric model is not capable of separating effects of climate on migration through the wage channel from direct effects of climate on migration through the amenity channel.

Building on the empirical approach used by Barrios et al. (2006), Feng et al. (2010) investigate international migration from Mexico to the U.S., focusing on the effects of climate
on migration through its effects on crop yields. They adopt the following two-stage model:

\[ M_{it} = \beta_0 + \beta_1 A_{it} + \gamma_t + \delta_i + \varepsilon_{it} \]  
\[ A_{it} = \mu_0 + \mu_1 Z_{it} + \tau_t + \eta_i + \nu_{it}, \]

where \( M_{it} \) is migration rate in Mexican state \( i \) and time \( t \), \( A_{it} \) is crop yield, \( Z_{it} \) is a vector of climate measures, and \( \varepsilon_{it} \) and \( \nu_{it} \) are random error terms. Time and state-specific fixed effects are included to account for the fact that there may be unobserved factors that are constant within states and within time periods that affect both crop yield and migration rate. Using weather as an exogenous instrument for crop yield allows Feng et al. to resolve potential omitted variables bias and to study the indirect relationship between climate and migration, which is of interest to their study. A problem with this approach, however, is that their instrument may not fully separate the effects of weather on migration through weather’s on crop yields from weather’s direct amenity effects. If individuals have direct preferences over the weather variables contained in \( Z_{it} \), the model may yield biased estimates of the effect of crop yield on migration. Nonetheless, estimating this model, Feng et al. find that a 10% decrease in corn yields increases the emigrating population by approximately 2 percentage points. Using estimates from the model’s first stage and climate change projections, they estimate that climate change will result in emigration of 4 million additional Mexicans to the U.S.

Feng et al. (2013) use a similar empirical design to investigate the effect of weather anomalies on migration within the U.S. corn belt. However, in order to more carefully identify the direct of crop yield on migration, they instrument crop yield with weather anomalies during corn flowering. During this time extreme heat has relatively severe impacts on crop yield. Moreover, unless preferences for weather amenities are highest during the corn flowering period, this instrument will better identify changes in migration specifically
due to agricultural productivity. They estimate that 10% decreases in crop yield would cause 30-40% of the population in a given county to emmigrate.

On the other hand, weather and climate can have affects on migration through direct amenity effects. While a variety of studies have investigated capitalization of weather amenities in home prices and wages, Rappaport (2007) provides one of the relatively few studies to emphasize the effects of weather amenities on migration. He regresses U.S. county-level population density growth rate on a series of weather variables, topographic variables, initial population density (to control for agglomeration effects), and variables measuring initial industry share of county employment. In models that include the latter set of variables, which are intended to control for changes in population density due to declines in industries potentially affected by climate, Rappaport finds significant effects of weather on changes in population density. Results indicate that an increase in mean winter temperature from 29 degrees to 54 degrees is associated with a 1.3% increase in county population growth rate. Therefore, weather amenities provide an explanation for high population growth in certain regions of the U.S. over the past century.

Marchiori et al. (2012) provide a rare example of a study that attempts to simultaneously investigate the effects of weather on migration through the wage and amenity channels. They focus on rural-urban migration in the developing world and extend the theoretical framework developed by Barrios et al. (2006) to allow that weather can affect migration through its affect on productivity in the rural sector and through an amenity channel. In addition, Marchiori et al. consider internal migration together with international migration, so that international migration is endogenous to internal migration. As in Barrios et al. (2006), their theoretical model comprises two sectors (urban and rural), sectors set wages equal to marginal productivity of workers, and wages within the rural sector depend on climatic factors. Rural workers migrate to urban areas if the wages in the urban area
are higher. Since rural wages depend on climatic factors, migration can be induced by shocks to climate. Some portion of urban workers within their model are internationally mobile. They migrate if the wages in the destination county plus losses due to amenity shocks outweigh wages in the source country. Therefore, climate can cause international migration in two ways. First, climate shocks may directly affect migration through the amenity channels. Second, climate can increase rural migration into urban areas, which depresses urban wages and causes increased international migration. On the other hand, as rural workers move into the urban sector, there may be agglomeration effects. In the presence of strong agglomeration effects, increased urbanization could decrease international migration.

Marchiori et al. (2012) construct a two-stage econometric model in which they estimate the effects of per-capita GDP, urbanization, and weather anomalies on international migration in sub-Saharan Africa. Since the ratio of per capita GDP inside the country to per capita GDP outside the country and the fraction of the country living in urban areas are both potentially endogenous, predicted values for these variables are generated in two first-stage equations using three instrumental variables related to monetary policy and national independence. They find that evidence that weather anomalies affect migration through amenities and through effects on agricultural production. Furthermore, their first stage results indicate that weather anomalies affect urbanization. Second stage results indicate that increases in urbanization weaken international emigration, consistent with strong agglomeration effects of cities.

3.2 Effects of environmental shocks on migration

Two recent studies by Hornbeck (Hornbeck, 2012; Hornbeck and Naidu, 2014) examine the effects of environmental shocks within the United States on outcomes for local economies,
including migration. The first of these studies the effects of the American Dust Bowl over
time. To estimate effects of erosion on various local economic outcomes, he assumes that
if not for erosion, economies of eroded counties would have changed over time similarly to
non-eroded counties. Therefore, he estimates:

\[ Y_{ct} - Y_{c1930} = \beta_1 M_c + \beta_2 H_c + \alpha_{st} + \theta_t X_c + \epsilon_{ct}, \]  

(3)

where \( M_c \) is the percent of county \( c \) in moderate erosion, \( H_c \) is the percent of county \( c \) in
high erosion, \( \alpha_{st} \) is a set of state-time fixed effects, and \( X_c \) is a vector of county-specific
variables. The dependent variable \( Y_{ct} - Y_{c1930} \) represents the change in outcome \( Y \) in county
\( c \) at time \( t \) relative to outcome \( Y \) in the base year. Hornbeck finds that high and moderate
erosion counties experienced decreases in population of 12% and 9%, respectively, by
1940. Under an assumption about the elasticity of labor demand and estimates of changes
in local consumption, Hornbeck estimates that estimated changes in labor supply (due to
migration) are of approximately the right size to explain labor market recovery. In other
words, as labor demand decreased due to the Dust Bowl, the labor market responded
primarily through changes in labor supply rather than recovery in labor demand through
investment in capital, adoption of new technology, or increases in alternative industries.
Hornbeck argues that the response of the labor market in this case may have been driven
in part by the time at which the Dust Bowl occurred. During the Great Depression, access
to capital was severely limited, which would have affected the ability of the labor market
to respond through investment or other means.

In a similar study, Hornbeck and Naidu (2014) examines the effect of the Great Missis-
sippi Flood of 1927 on out-migration of blacks in flooded counties. Here he finds that black
populations migrated out of flooded counties, and that these counties responded by increasing
investment in capital. He suggests that the predominantly white labor force left behind
after out-migration of blacks in these counties was complementary with greater investment
in capital. While Hornbeck (2012) and Hornbeck and Naidu (2014) examine events with severe and sudden local effects, they may nonetheless have relevance for studies of the effects of climate change on migration. Together, these studies emphasize the importance of analyzing the characteristics of local economies that may enable or prevent labor markets from adapting to shocks through means other than migration.

### 3.3 New Economics of Labor Migration

Few studies have considered the effect of climate on migration within the context of NELM models. The first example of such a study is provided by Rosenzweig and Stark (1989), which hypothesizes that household intermarriage decisions in India are made in part due to household risk mitigation strategies. This hypothesis implies that agricultural households, which are exposed to greater risk due to weather shocks, will arrange marriages with households located a greater distance apart, where weather shocks are unlikely to be highly correlated. Household ties formed by intermarriage can then be used to help households smooth consumption in the face of shocks to productivity. To test this hypothesis they use data from a 10-year panel survey of households in India. They model relationships between a series of relevant dependent variables and household income variance and mean. To control for unobserved household characteristics that might affect dependent variables and households’ income distributions, such as household risk mitigation strategies other than intermarriage, Rosenzweig and Stark instrument for income mean and variance using rainfall data interacted with household landholdings. They find that the number of migrants within the household increases with income variance, but decreases with household wealth. Similarly, average marriage distance increases with income variance and decreases with wealth, consistent with the paper’s hypothesis.

Another example using weather data in the context of NELM models is Yang and
Choi (2007). This study addresses the NELM hypothesis that households’ international remittance payments are used by households as insurance. When household members in the source country (in this case the Philippines) experience weather shocks, natural disasters, or other events that affect household income, remittances from household members located abroad can be used to smooth the income of household members remaining in the source country. Yang and Choi (2007) cannot examine the effect of income on the size of remittance payments directly, because families that receive higher remittance payments may be capable of making productive investments that increase household income. Therefore, simultaneity between remittance payments and income should lead to upward bias in direct estimates of the effect of income on remittances. To resolve this problem, Yang and Choi instrument for household income using local rainfall data for household members within the source country. Furthermore, unlike many of the studies reviewed here, Yang and Choi make use of panel data obtained from household surveys within the Phillipines. This allows them to control for unobserved household-specific characteristics that might affect both household income and remittances.

First stage estimates indicate that increases in rainfall during the dry season are associated with increases in income. Second stage results show that, among households containing migrant members, decreases in income caused increased remittances, though standard errors are quite large. Yang and Choi also examine whether income shocks cause an increase in the probability that households have a member working abroad. They find no effect among households who already have a member working abroad at the beginning of the panel. However, they find some evidence that increases in household income increase the likelihood that households without a migrant member at the beginning of the panel will have a member working abroad at the end of the panel. This is evidence that some households may be credit constrained; when income increases, these households may be more
willing to invest in migration.

4 Discussion

This paper reviewed the relevant theory and existing evidence regarding the effects of environmental changes on migration. The picture that emerges from this literature is that environmental change can cause migration both through its effects on wages and amenities. Projected migration due to climate change varies in size, but is typically not as severe as suggested by Stern (2006). Still, very little is known on this topic and significant work is needed. Most of the empirical papers examining effects of environmental change on migration rely on aggregate data, which may mask underlying trends (for example, see Sjaastad 1962). In papers such as Feng et al. (2013), migration due to climate change over the next 100 years is predicted based on responses to weather over the past 40 years. Hornbeck (2012) indicates, however, that migration-responses may be highly particular to other economic conditions, that either enable or prevent adjustment within the labor market through other means. Therefore, if we would like to better predict the effects of climate change on migration, it may be important to understand how labor markets currently respond to changes in climate. Moreover, if we are particularly concerned about potential effects of climate change on migration within the developing world, increased study within that particular context is needed, though researchers in this area will need to contend with the difficulty of obtaining data.

Examples for this how this research could proceed may come from Hornbeck (Hornbeck, 2012; Hornbeck and Naidu, 2014), who details the effects of environmental change on a variety of outcomes within local economies. These studies are more informative than the typical study using aggregate data on net migration and climate because they also provide
insight into what factors may have attenuated or enhanced migration responses. One problem with this approach, however, is that it may rely on severe events with clear boundaries (such as floods) for sufficient variation. The approach may need to be modified to study gradual changes such as climate change. The significant challenges facing researchers may explain the current paucity of research on the topic. Nonetheless, effects of environmental change on migration may be highly relevant in coming years, and more research in this area is needed.

References


