Climate and International Migration: The Importance of the Agricultural Linkage

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Preliminary draft - do not cite or quote

Abstract

While there has been considerable interest in understanding the complex climate-migration relationship given concerns about global climatic changes, little is known about the relative importance of various intermediate mechanisms underlying such a relationship. Here we analyze a unique and extensive set of panel data characterizing bilateral international migration flows covering the last three decades. We show that a strong positive relationship between temperature and international outmigration is detected only in the most agriculture-dependent countries, due to the adverse impact of temperature on agricultural productivity. In addition, migration flows to current major destinations are especially temperature-sensitive. Therefore, international agencies and national governments developing policies to address issues related to climate-induced international migration would be more effective if focused on the agriculture-dependent countries and especially people in those countries whose livelihoods depend on agriculture.

Keywords: climate change; temperature increase; international migration; agriculture

JEL classification: F22, O13, Q01

1. Introduction

In recent decades, climate change, especially temperature increase, has become an increasing global concern, as its actual and potential are understood in greater detail (IPCC, 2007). One widely cited impact is the possible large-scale displacement of segments of human population (Myers, 2002; Stern, 2007; Warner et al., 2009). Among all climate-induced migrants, those crossing the political borders would be a matter of special concern as both receiving and sending countries are affected. National governments and international agencies need to understand the mechanisms underlying the climate-migration relationship in order to devise policies to identify potential sources and receiving regions and to effectively manage migration flows.

There is a large literature on human migration that encompasses several disciplines. Nevertheless, the quantitative literature on weather and climate induced migration is still in its infancy, despite growing interest from policymakers and the general public. The empirical results so far are mixed – while many studies support a significant relationship between migration and climate related conditions such as natural disasters, temperature, precipitation (Reuveny & Moore, 2009; Feng, Krueger, & Oppenheimer, 2010; Feng & Oppenheimer, 2012; Marchiori, Maystadt, & Schumacher, 2012; Gray & Mueller, 2012), some researchers find climate an inconsequential factor compared to other drivers of migration (Mortreux & Barnett, 2009; Naudé, 2010). The elation between sensitivity of migration to climate and weather variability and future migration due to long term climate change is uncertain. Here we focus on the former which provides insights on current motivations for migration while potentially informing projections of the latter. Such apparent inconsistencies arise partly because the existing studies are mostly context specific – they differ in the measurements of climate factors, geographic regions covered, and the time frames of study. The effects of climate on human migration are likely to be heterogeneous, as climate may interact with region-specific push and pull factors, such as socio-economic and environment conditions, culture and lifestyle, social networks, and so on (Black, Kniveton, & Schmidt-Verkerk, 2011). To move this literature forward and gain a more complete picture of the climate-migration relationship, one can either continue to accumulate such context-specific evidences or conduct the analysis at a more aggregate level and focus on the most important linkage(s).

This paper takes the second approach, and considers agriculture to be a possible candidate for the most important intermediate link between climate and (international) migration for the following reasons. First, agriculture is an important economic sector in many countries, especially in the developing world, where a large proportion of the population still directly depends on agriculture for a living. Second, agricultural declines induced by slow-onset climate changes are a plausible causal mechanism for long term population shift (Piguet, Pécoud, & De Guchteneire, 2011). In contrast, other channels for the influence of climate change are likely to either affect only a specific type of region (such as sea level rise that is only directly relevant to coastal regions), or tend to displace people only temporarily, such as flood or cyclones (cite Pratikshya's draft paper). Last but not least, a large body of literature has already established severe adverse effect of climatic changes, especially temperature increase, on crop yields (Lobell et al., 2008; Schlenker & Roberts, 2009; Lobell, Schlenker, & Costa-Roberts, 2011). On a more aggregate level, Dell et al. (2012) found that GDP growth rates are negatively associated with temperature, but only for less developed countries which are more dependent on agriculture. Given that income, usually proxied by GDP per capita in empirical work, is a major determinant of international migration (Borjas, 1989), it is reasonable to expect agriculture to play an important role in the climate-migration relationship.

In this paper, we use a comprehensive bilateral annual migration data covering 42 OECD destination countries and 160 origin countries over the period of 1980-2009 to study the climate-migration relationship empirically. We first estimate a reduced-form model that links origin country weather variations to its international outmigration. To investigate the role of agriculture, interaction terms between weather and agriculture-dependency are included in the regression. We find that the effect of temperature on outmigration is positive and statistically significant only in the most agriculture-dependent countries. Because these agriculture-dependent countries are also poor countries in general, we provide further evidence to rule out the "poor country" effects. We estimate the yield-migration relationship, using temperature and precipitation as instruments in the first stage, as in Feng, Krueger, and Oppenheimer (2010). Once again, we find that outmigration is highly responsive to climate-induced yield shocks, but only in agricultural countries. Our results thus suggest that, globally, agriculture may be the most important intermediate link between climate and international migration.

The findings of our paper should provide some guidance to those developing policies to anticipate and manage these flows by focusing attention on agriculture-dependent countries and especially people in those countries whose livelihoods depend on agriculture. Adaptation in the agricultural sector, which builds resilience and enhances farmers' earnings capacities, may also reduce incentives to migrate. Diversifying livelihoods for those who now depend on agriculture, such as by encouraging off-farm work, urbanization or structural upgrading, also has the potential to reduce cross-border migration.

The rest of the paper proceeds as follows. Section 2 reviews the emerging literature on climate-induced migration. Section 3 presents a theoretical model of international migration that incorporates climate formally and introduces our empirical strategies. The model shows that agriculture-dependent countries are likely to experience more outmigration as adverse climate shocks hit. In section 4, we present our empirical results, followed by our conclusions in the final section.

2. Literature Review

Although many theories about international migration have been developed (see the review article by Massey et al., 1993, for example), the most prominent one is the neoclassical economics model which hypothesizes that migration is driven by income maximization (Roy, 1951; Borjas, 1989). Simply put, a potential migrant is assumed to compare the income differences among source and several destination countries and the travel cost, and select a destination country which maximizes his/her income. This framework has been employed in numerous migration studies (Clark, Hatton, & Williamson, 2007; Mayda, 2010; Beine & Parsons, 2012; Marchiori, Maystadt, & Schumacher, 2012).

The income maximization framework can be extended to utility maximization in order to incorporate non-pecuniary determinants of migration (Borjas, 1989; Massey et al., 1993), such as cultural and linguistic distance, political pressures, conflicts and wars, networks of family and friends, educational pulls, social benefits, immigration policies, amenities, and so on (Adams, 1993; Massey et al., 1993; Borjas, 1999; Clark, Hatton, & Williamson, 2007; Pedersen, Pytlikova, & Smith, 2008; Ortega & Peri, 2009; Mayda, 2010; Adsera & Pytlikova, 2012). During recent decades, climatic and environmental factors have also received more and more attention in the literature. Researchers have considered the association of many climatic and environmental related factors with migration, such as sea level rise, environmental degradation, weather-related crop failures, and extreme weather events (Hugo, 1996; Myers, 2002; Warner et al., 2009; Piguet, Pécoud, & De Guchteneire, 2011; Foresight, 2011; Gray & Mueller, 2012).

Many studies found climate to be affecting significant influence on migration. Using unbalanced panel data, Barrios, Bertinelli, and Strobl (2006) found that rainfall is likely to affect rural-to-urban migration in sub-Saharan Africa. Feng, Krueger, and Oppenheimer (2010) and Feng and Oppenheimer (2012) used a Mexican state-level panel data of migration flows, and found a significant semi-elasticity of migration from Mexico to the United States with respect to climate-driven changes in crop yields. Gray and Mueller (2012) showed that crop failures driven by rainfall deficits have a strong effect on mobility in Bangladesh, while flooding only has a modest effect. Based on a country-level panel data for sub-Saharan Africa, Marchiori, Maystadt, and Schumacher (2012) found that "weather anomalies" increase internal and international migration through both amenity (direct effect) and economic geography (indirect effect) channels.

In contrast, some other studies have not found a significant role for climate. Based on a survey conducted in Tuvalu, Mortreux and Barnett (2009) showed that the vast majority of potential migrants do not consider climate change as a possible reason for leaving the country. Naudé (2010) also reported that natural disasters do not have significant effects on international migration across sub-Saharan African countries. However, these studies have not considered possible indirect impact of climate through income differences and other channels. For example, in the survey data used by Mortreux and Barnett (2009), migrants might not be aware of the possibility that climate change also implicitly contributes to socio-economic shocks which directly affect migration, and thus "do not cite climate change as a reason to leave". When discussing the insignificant effects of natural disasters on migration, Naudé (2010) also acknowledged that natural disasters may "affect conflict and job opportunities (GDP growth) and, as such, have an indirect impact on migration".

Due to data limitations, most previous studies on the determinants of migration relied on analyses of migrants moving to one destination from one origin country (Massey & Espinosa, 1997; Feng, Krueger, & Oppenheimer, 2010) or to one destination from multiple origin countries (Vogler & Rotte, 2000; Karemera, Oguledo, & Davis, 2000; Hanson & McIntosh 2010; Clark, Hatton, & Williamson, 2007). More recently, analysts of international migration begin to rely on multi-country bilateral migration data, which increases the quality of data and allows for more general and robust conclusions (Ortega & Peri, 2009; Mayda, 2010; Groschol, 2012), though its application in the climate-migration studies is still limited. Reuveny and Moore (2009) used a cross-sectional data of bilateral international migration flows to 15 OECD destination countries in the late 1980s and 1990s. Beine and Parsons (2012) used a panel of bilateral migration flows for the period of 1960-2000 from

Özden et al. (2011). Their dataset is comprehensive except that there are only five panels, as it is based on the last five completed census. Martinez-Zarzoso, Murris, and Backhaus (2012) used a bilateral international migration data over the period 1996-2006, with migration flows from 161 origin countries to 19 OECD countries. In this study, we use a more comprehensive bilateral annual migration data which allows a more thorough analysis of the relationship between climate and international migration. In addition we have data on both migration flows and foreign population stocks, which allows us to investigate the role of migration networks, among others,

3 Theoretical framework and Empirical specifications

3.1 Theoretical Model

Suppose there is a fictitious country (FC), which is a small open economy compared with the rest-of-the-world (ROTW). Initially FC is populated by a mass normalized to 1. The utility of person *i* in FC is:

$$U_i = w + p + a_i \quad (1)$$

where w is the wage, p is the deterministic part of the non-pecuniary utility, and a_i is the individual deviation from the average non-pecuniary utility. Therefore, by construction the expectation of a_i is 0, with cumulative distribution function $F(.)$. The higher a_i, the more person *i* prefers to remain in FC.

Suppose now we allow people from FC to migrate to ROTW (but not otherwise). Let the wage level in ROTW be w_r. For simplicity, we assume that people originally from FC do not enjoy any non-pecuniary utility in ROTW. Thus, a person *i* would have the utility level of just w_r in ROTW. Alternatively, one can consider $p + a_i$ as the utility premium for person *i* to live in FC.

To migrate from FC to ROTW, a person must also incur a cost of c. Thus, according to Borjas (1987)'s model, the equilibrium condition for any person *i* to remain in FC is:

$$w + p + a_i \geq w_r - c \quad (2)$$

The marginal person *j* is defined as the one who is just indifferent between living in FC and migrating to ROTW, i.e., for person *j*,

$$w + p + a_j = w_r - c \quad (3)$$

Thus, in the equilibrium, the total population in FC is $N = 1 - F(a_j)$, where a_j is implicitly defined as in (3).

Suppose in FC, the aggregate production function is $Y = [\alpha A + (1-\alpha)B]K^{\beta}N^{1-\beta}$, where K is capital, N is totallabor force, which equals the total population for simplicity, A is the productivity of agricultural sector, B is the productivity of non-agricultural sector, and we have the assumption that $B > A$, i.e., non-agricultural sector is more productive. α is the proportion of agricultural sector in the economy. β is the output elasticity of capital, and $1-\beta$ is the output elasticity of labor.

If the labor market is competitive, the real wage should equal the marginal productivity of labor. Thus the equilibrium wage level in FC is determined by the following first order condition:

$$w = \frac{\partial Y}{\partial N} = (1-\beta)[\alpha A + (1-\alpha)B](K/N)^{\beta} \tag{4}$$

Now, let's consider how climate change affects outmigration from FC. Let C stand for the adverse climate factors, such as the departure of temperature and precipitation from its normal range. Based on empirical findings of Dell et al. (2012), we assume climate affects the productivity of agricultural sector but not that of non-agricultural sector, i.e., $\frac{\partial A}{\partial C} < 0$ and $\frac{\partial B}{\partial C} = 0$.[1] We also allow the possibility that adverse climate condition would affect people's expected amenities in FC, and $\frac{\partial p}{\partial C} \leq 0$.

Rewrite (3), we have:

$$(1-\beta)[\alpha A(C) + (1-\alpha)B](K/N(C))^{\beta} + p(C) + F^{-1}(1-N(C)) = w_r - c \tag{5}$$

Take derivatives with respect to T in both sides of equation (5),

$$\frac{dN}{dC} = \frac{(1-\beta)\alpha\frac{\partial A}{\partial T}(K/N)^{\beta} + \frac{\partial p}{\partial C}}{(1-\beta)\beta[\alpha A + (1-\alpha)B](K/N)^{\beta}(1/N) + F^{-1'}(1-N(C))}, \tag{6}$$

According to Equation (6), we have the following results:

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[1] We make this assumption for simplification. In reality, climate change may have effects on non-agriculture sectors as well. However, literature found strong effects of climate change on agriculture, while its effects on other sectors are relatively weak.

(a) $\frac{dN}{dC} < 0$, i.e., adverse climate change would induce a decline in population, or outmigration from the country;

(b) For countries that are more agriculture-dependent, i.e., with larger α, an adverse climate change would trigger more outmigration. This follows as A<B;

(c) If amenities are not adversely affected by climate, i.e., $\frac{\partial p}{\partial C} = 0$, then for non-agricultural countries (with $\alpha = 0$), changes in climate would not trigger any outmigration ($\frac{dN}{dC} = 0$).

3.2 Empirical specification

To empirically test the main implications of the model, we estimate the follow regression:

$$\ln m_{ijt} = \beta_0 + \beta_1 TMP_{it} + \beta_2 PCP_{it} + \delta_1 TMP_{it} * A_i + \delta_2 PCP_{it} * A_i + \phi x_{it} + \varphi z_{jt} + \theta_{ij} + d_i year_t + \varepsilon_{ijt} \quad (7)$$

where m_{ijt} denotes migration rate, i.e., migration flow from origin country *i* to destination country *j* divided by the population of the origin country *i* at time *t*. TMP_{it} represents the population-weighted annual average of monthly mean temperature in the origin country *i* with a unit of degree Celsius.[2] PCP_{it} represents the population-weighted annual average of monthly total precipitation in the origin country *i* with a unit of millimeter.[3] A_i is a dummy variable that equals 1 if country *i* is defined as agriculture-dependent, 0 otherwise. x_{it} and z_{jt} are other control variables specific to origin country *i* and destination country *j*, respectively, such as the lagged GDP per

[2] We focus on international migration, for which the slow onset weather phenomenon is expected to have larger effects, as Piguet, Pécoud, and De Guchteneire (2011) summarized that "rapid onset phenomena lead overwhelmingly to short-term internal displacements rather than long-term or long-distance migration." Thus we use annual average temperature and precipitation as climate measures. Rapid onset extreme events, such as flooding or heat waves, still contribute to the annual average weather. Since our dependent variable – international migration which is more likely to be permanent as compared to internal migration, the model is by design intending to measure the effects of slow onset weather changes, and thus how much rapid onset extreme events contributes to the annual average weather should not affect our measurement of weather effects much.

[3] In studies of climate impact on agriculture, growing season weather variables are usually used. However, for cereal yields (including corn, rice, wheat, and many more) from all the countries, growing seasons are rather diverse, so annual weather variables are a better choice.

capita. θ_{ij} denotes country-pair fixed effects, which captures time-invariant unobserved characteristics between two specific countries, such as distance, historical and cultural ties, as well as bilateral immigration policy schemes. $d_i year_t$ denotes origin country-specific linear time trend, which helps to account for factors evolve over time within specific origin countries. ε_{ijt} denotes the error term. In our empirical work, we always report robust standard errors clustered at the country pair level to allow for within-country-pair correlations in the error term. $\beta_0, \beta_1, \beta_2, \delta_1, \delta_2, \phi,$ and φ are parameters. The key parameters of interest are δ_1 and δ_2 , which capture the differential climate effects in agriculture-dependent countries versus the other countries.

To provide more direct evidence on the role of agriculture as the intermediate linkage between climate and outmigration, we an empirical strategy similar to Feng, Krueger, and Oppenheimer (2010) and Feng, Oppenheimer and Schlenker (2012) and estimate the elasticity of migration with respect to cereal yields. Our two-stage least-squares (2SLS) regression model is as follows:

$$\ln Y_{it} = \beta_0 + \beta_1 TMP_{it} + \beta_1 PCP_{it} + f_i + d_i\, year_t + \varepsilon_{it} \qquad (8)$$

$$\ln m_{it} = \gamma_0 + \gamma_1 \ln Y_{it} + h_i + c_i\, year_t + \mu_{it} \qquad (9)$$

In the first stage, the natural logarithm cereal yields are regressed on annual average of monthly mean temperature and monthly total precipitation. In the second stage, the natural logarithm of outmigration rate is regressed on predicted cereal yields from the first stage. f_i and h_i denote country fixed effects, $d_i\, year_t$ and $c_i\, year_t$ stand for country-specific linear time trends. Unlike the reduced-form model shown in (7), in the 2SLS specification, we aggregate outmigration to all destination countries for each sending country.

4. Empirical results

4.1 Data and Summary Statistics

We use unique data on bilateral international migration flows collected by M. Pytlikova, containing immigration flows and stocks of foreigners in 42 OECD destination countries from all the countries during the period 1980-

2009.[4] It was collected by writing to selected national statistical offices of OECD countries to request detailed information on immigration flows and foreign population stocks in their respective country, sorted by origin country. Although our dataset presents substantial progress over similar datasets used in past research such as the data from Docquier and Marfouk (2004), the United Nations, the OECD, and the World Bank, it is not without limitations. First, the data set is unbalanced, with missing migration flows and stocks for some countries in some years. However, missing observations become less of a problem for more recent yearsFor an overview of comprehensiveness of observations of flows across all destination countries over time, see the Appendix Table A1. Second, as in the other existing datasets, different countries use different definitions of an “immigrant” and draw their migration statistics from different sources, see the Appendix Tables A2 for a detailed overview of definitions and sources for data on immigration flows and foreign population stock, respectively.Nevertheless, both types of measurement errors are unlikely to be correlated with weather patterns and cause biases to our parameter estimates.

Socio-economic factors, such as the agricultural ratio[5] and cereal yields were collected from the World Bank. The purchasing power parity Converted GDP Per Capita at 2005 constant prices was obtained from the *Penn World Tables Version* 7.0 (Heston, Summers, & Aten 2009). Global gridded monthly mean temperature and total precipitation data from 1980 to 2009 were collected from NASA MERRA with a resolution of 2/3 degrees in longitude and 1/2 degrees in latitude, and then aggregated to be country-level population-weighted, so that the weather conditions for populated regions within a country are given more weights.

Our migration data covers 160 origin countries, and 42 of them are also destination countries, with a total of 95,856 observations during the time period of 1980-2009. On average, for an origin country, a total number of about 1,078 people migrate to another specific country during a specific year. During the period of 1980-2009, there were in total about 104 million people migrating to another country; among them, about 83 million (48 million) people migrated through the top 5% (1%) migration routes by country pairs. Table 1 presents more detailed information about our data. We observe that non-agricultural countries on average have higher outmigration rates. This may be due to the fact that most agriculture-dependent countries are also poor countries,

[4] The original OECD migration dataset by Pedersen, Pytlikova and Smith (2008) covers 22 OECD destination and 129 origin countries over the period of years 1989-2000. The dataset has been extended further to cover 30 OECD destinations, all origin countries and years 1980-2009 by Adsera and Pytlikova (2012)

[5] The agricultural ratio is defined as the share of agriculture value-added in total GDP.

which usually have limited out-migration flows due to poverty constrains (Hatton and Williamson, 2005 and 2011, Clark et al. 2007, Pedersen et al. 2008; Docquier and Rappaport, 2012; Belot and Hatton, 2012). GDP per capita and cereal yields are lower for agricultural countries. Agricultural countries have on average higher temperatures as they are more likely to be located in lower latitude regions than non-agricultural countries. Agricultural countries also tend to have higher precipitation. In our empirical work, we define agricultural-dependent countries as the top 25% countries (column 4 of table 1) in terms of the agricultural ratio, although we will also show robustness check results that use different cut-off thresholds, such as 20% or 33%.

4.2. The reduced-form regression results

Table 2 first shows results from the most parsimonious model that only includes the temperature, interaction of a dummy for agricultural country and temperature, and a constant to the full specification. Column (2) adds precipitation and its interaction with agricultural dummy into the model. In our preferred specification shown in Column (3) we regress the log migration rate on contemporaneous temperature and precipitation in origin countries and lagged GDP per capita for both origin and destination countries. Interaction terms between temperature and agricultural dependence are also included to test if the temperature effect is different between the top 25% agriculture-dependent countries (as measured by the percentage of agricultural sector GDP in total GDP) and the rest of countries. All models contain also a set of country pair fixed effects and origin-country specific time trends. In Table 2, a positive and significant coefficient estimate for the interaction term suggests that the temperature effects are significantly different between agricultural and non-agricultural countries, and temperature is more likely to induce significant outmigration from agricultural countries. Specifically, based on column (3) of Table 2, each 1 °C increase in temperature leads to about 5.1% immediate increase in total migration from agricultural countries, as compared to only 0.4% increase in migration from other countries. The results hold whether we control for GDP per capita or not, as shown in columns (2) and (3).

In Table 3, we present a number of robustness checks. Our main results are qualitatively the same whether we use different control variables (Panels A-F), different regression techniques (Panel G), different dependent variables (Panel H), or slightly different samples (Panels I-K). When conducting robustness checks, we also allow different thresholds for the definition of agriculture-dependent countries – top 33%, 25%, and 20% countries by the agricultural ratio, as shown in different columns in Table 3. In general, the differential temperature effects for agriculture-dependent countries become larger in magnitude and more statistically significant when a higher threshold is set to identify agriculture-dependent countries, as we go from column (1) to column (3) in Table 3. The results are thus consistent with the idea that more agricultural countries are more likely to experience outmigration when temperature rises, as shown in our theoretical model.

The temperature effects become slightly weaker but still significant when the lagged terms up to five years are added (Table 3. Panels A and B). This implies that temperature may have some lagged effects as it may take some time to stimulate international migration. In Panel C, we found that our results hold (although slightly weaker) when the lagged migration stock is controlled for. This is to address the concern that migration flows may be largely determined by migration stock (Foreign population from country i residing in country j) which is likely to be a proxy for migrant networks, i.e. networks of family members, friends and people of the same origin that already live in a host country (Munshi, 2003). We also used the lagged dependent variable – the lagged natural logarithm of migration rate as one of the independent variables (Panel D), since the migration rate (Migration flows ratios per source country population) may be serially correlated. Again, we found that this dynamic panel model has weaker but similar results as our baseline specification. This specification in Panel D could also be viewed as an alternative way to control for migrant networks as Panel C.

In Panel E, the temperature effects are still positive and significant when we include a country-specific quadratic time trend, which controls for some nonlinear determinants of migration trending over time for each country. We used country-pair fixed effects in the baseline specification, while the separate country fixed effects for origin and destination countries were chosen as baseline specifications for additional studies (Ortega and Peri, 2009; Mayda, 2010): we control for the separate country fixed effects and also other variables such as distance, common language, colonial tie, and common border which were not included in the model with country-pair fixed effects since they were absorbed by country-pair fixed effects (Ortega and Peri, 2009). With this alternative fixed effects specification (Panel F), the temperature effects are still positive and significant for both top 25% and 20% agriculture-dependent countries.

In panel G, we run a weighted least squares regression using country total population as weights. We found that, although still positive across all columns, only the estimate for the top 20% agriculture-dependent countries is still statistically significant (column 3), which is in line with Gröschl (2012). To understand the reason for this weakened temperature effects, we split the sample into halves by population size, and found that only less populated countries have a significant and positive relationship between temperature and migration.[6] This could be due to the fact that the country-level climate data are less precise for big countries. By giving more weight to a country with larger population, we actually enlarge the influence of countries with less precise climate measures. Another possibility is that a bigger country tends to have more room for internal migration (Gröschl, 2012), which reduces the responsiveness of international migration to temperature changes.

We also test the case when the natural log of migration flow (Panel H), instead of the natural log of migration rate, is used as dependent variables. The results are very similar to that of baseline specification.

Finally, we perform some tests to rule out the possibility that the results are driven by some outlier countries or country pairs. As we mentioned earlier, during the past three decades, 83 million (48 million) out of 104 million migrants are occurred in the top 5% (1%) migration routes (country pairs). Now we remove the data from the top 5% (1%) migration routes in Panel I (Panel J) of Table 3 and found that the effects are still positive and significant across all definitions of agriculture-dependency. In addition, about 11% of all the country pairs do not have any migration flows. In Panel K, we drop zero migration flows from the sample and rerun the regressions. The coefficient estimates for the interaction term are similar in magnitude and remain statistically significant.

We do not interpret the precipitation coefficients here, since statistical methods appear more reliable for temperature variables (Lobell & Burker, 2010), this may be explained by the fact that precipitation has higher spatial variability and thus is less well captured than temperature by the relatively coarse climate data" (Burker et al., 2009). When applied to projections, it is also acceptable to focus on temperature coefficients only, since predictions of future temperatures over the next few decades are more uniform than that of precipitation" (Burke et al., 2009). However, it is still important to control for precipitation as a confounding factor. As column (1) of Table 2 shows, the temperature coefficient becomes less significant when precipitation is not included in the model.

We further study the role of destination countries in climate-induced migration. In Table 4, when we stratify the sample by destination country for each origin country, we found that our main results – positive temperature effects on outmigration from agricultural-dependent countries – are only detected when their top 25% migration destination countries are used, as compared to the rest of the destination countries. The results imply

[6] The results are not included in this paper for brevity but are available upon request.

that temperature tends to intensify migration mostly in the already established migration routes, while it has insignificant immediate effect on migration to the countries which are previously not major destination countries.

4.3 Two-Stage Least Squares regression Results

The finding of a strong positive relationship between temperature and outmigration only for agricultural-dependent countries is quite revealing, but does not yet provide a definite answer on whether agriculture played an important intermediate role, as many such countries are also very poor. To rule out the "poor country" effect, one needs to provide more direct evidence on the role of agriculture.

In this subsection, we estimate the relationship between cereal yields, an indicator of agricultural productivity, and international outmigration. To deal with the biases caused by reverse causality and omitted variables, we use temperature and precipitation to instrument for cereal yields and use the FE-2SLS method to estimate the equations (8) and (9). To the extent that climate factors are conditional exogenous, the FE-2SLS is consistent; see Feng, Krueger, and Oppenheimer (2010) and Feng and Oppenheimer (2012) for more discussions.

Tables 5 and 6 contain the first and second stage results of the instrumental variables approach for four country groups categorized based on the agricultural ratio. Consistent with our reduced-form regression results, when using temperature and precipitation as its instruments, cereal yields are found to be negatively associated with outmigration only in the top 25% agriculture-dependent countries (Table 6, column 4), suggesting that cereal yields appear to be an important factor for migration, consistent with earlier empirical studies (Feng, Krueger, & Oppenheimer, 2010; Feng, Oppenheimer, & Schlenker, 2012). In particular, the estimated elasticity of outmigration rate with respect to cereal yields in the top 25% agriculture-dependent countries is about 1.6. To put the number in perspective, for a country with 0.1% annual outmigration rate, a 10% reduction in cereal yields would raise the annual migration rate by around 16%, or to 0.116%. Table 6 also shows that the 2SLS estimates are substantially different from the OLS estimates (Table 6) and more negative, which implies that the unobserved omitted variables jointly determining cereal yields and migration would bias the OLS estimates towards zero.

A concern for the instrumental variables approach is the weak instrument. In Table 5, although F-statistics of the instruments in the first stage are all significant at the 95% level, all of them are less than 10, a value usually used as a rule of thumb to detect weak instruments (Staiger & Stock, 1997). However, this rule of thumb is only for regular standard errors while we report robust standard errors clustered at the country level. In addition, we are not much concerned about the relationship between yields and climate being weak, as there are many existing studies showing a strong and significant relationship between the two (see e.g. Schlenker & Roberts, 2009; Lobell, Schlenker, & Costa-Roberts, 2011). On the other hand, the slightly low F-statistics reported here might be due to imprecise measurements of climate and yields. Country level data are relatively coarse for both weather and cereal yields; thus the correlation between them are expected to be less significant than is the case when finer subnational data are used. This is especially so in consideration of the possible nonlinear relationship between temperature and yields (Schlenker & Roberts, 2009). Meanwhile, cereal includes multiple crops such as corn, rice, wheat, and many more, which have different growing season, and also different sensitivities to weather variations. Additional noises are introduced when pooling them together, as we do in this paper.

Another, probably more serious, concern is whether or not our exclusion restriction is valid. If weather also affects migration through channels other than cereal yields, the 2SLS estimates would still be biased. Because we are focusing on average temperature, it is unlikely that its change would induce sudden direct outmigration as extreme weather events would do (Piguet, Pécoud, & De Guchteneire, 2011). Nevertheless, there are still remaining concerns. For example, if people have a direct preference to live in less hot areas, our 2SLS estimates would be biased upward. However, if this is the case, we would expect a negative and significant coefficient even for non-agricultural countries, i.e., non-agricultural countries serve as a control group in our empirical methodology. Fortunately, this is not the case. As shown in Table 6, except for the top 25% agricultural-dependent countries, for all other countries (columns 1-3) we cannot reject the null of zero coefficients. This is also consistent with our findings reported in Table 2, which shows no reduced-form relationship between temperature and outmigration for non-agricultural countries.

We conduct several robustness checks for the instrumental variables approach results in Table 7. In addition to the 2SLS results, we also performed the Limited Information Maximum Likelihood (LIML) estimations. The results are in general quite robust to various model specifications. First, to alleviate concerns regarding weak instruments, we use either only temperature or only precipitation as the instrument, as it is well known in the econometrics literature that the use of fewer instruments reduces the possible weak instrument bias (Angrist & Pischke, 2008). The results are shown in Panels A and B in Table 7. The result using temperature as the only instrument is quite similar to the baseline specification, while when precipitation is used as the only instrument, the coefficient is slightly smaller but still significant at 10%, as the average precipitation data at the country level may not be reliable.

In Panel C, we use the one year lagged climate variables and cereal yields in the regression. In Panel D, we include GDP per capita as an additional control variable, as income is frequently used as a main explanatory variable in studies of international migration. In Panel E, we try an alternative definition of migration, using the natural log of migration flows rather than the natural log of migration rate as the dependent variable. In all these cases, the coefficient estimates remain negative and statistically significant.

Lastly, we alter our definition of agricultural dependence somewhat. Instead of using only top one-fourth (25%) agriculture-dependent countries as in the baseline specification, we use the top one-third (33%) and top one-fifth (20%) of the agricultural countries in panels F and G, respectively. The estimated coefficients are very close to the baseline results, suggesting that the threshold for agricultural dependency that we use was not the key.

5. Conclusions

In this study, we employ both reduced-form model and instrumental variables approach to quantify the effects of weather variations on global bilateral international migration flows. Both approaches show that temperature has positive and statistically significant effects on outmigration, but only from agriculture-dependent countries. This result is robust to alternative model specifications in both approaches. Therefore, among the intermediate links between climate and international migration, agriculture appears to be an important one. Overall, our results suggest that significant climate-induced international migration only happens in a small group of agriculture-dependent countries; however, the consequences may be substantial since we find that climate-induced migration specifically enlarges the flow in already significant migration routes, potentially presenting challenges to major migrant-receiving countries, mostly industrialized countries. Studies such as this one could provide a basis for advanced consideration of policies to address the consequences (both positive and negative) of potential increases in immigration due to climate change.

This study provides robust empirical evidence that agriculture is a significant factor influencing climate-induced international migration. Most previous studies are region-specific, thus less likely to identify a general factor and yield mixed results. Future research should further test our results as better migration and climate data becomes available. While we perform the analysis using the reduced-form model and instrumental variables approach, alternative methods and tools should also be used to study the climate-migration relationship where it is appropriate.

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Table 1. Descriptive Statistics

	Four equal-sized country groups by the agriculture ratio (1)	(2)	(3)	(4)	All the Countries
Total outmigration (millions)	37.322	23.164	33.453	7.926	104.456
Total outmigration in top 5% migration routes (millions)	27.293	17.878	26.949	6.406	82.576
Total outmigration in top 1% migration routes (millions)	16.046	8.797	15.820	3.842	48.310
Average annual outmigration rate	0.18% (0.19%)	0.29% (0.38%)	0.17% (0.32)	0.10% (0.31%)	0.10% (0.31%)
GDP per capita (2005 US dollar)	23485 (13183)	8894 (5924)	3161 (2109)	1413 (2248)	9443 (11734)
Cereal yields (Kilogram per hectare)	3659 (2010)	2571 (1546)	1994 (1186)	1495 (929)	2432 (1677)
The percentage of agriculture, value added in GDP	3.56% (2.22%)	10.22% (4.29%)	20.95% (6.72%)	39.08% (11.47%)	18.32% (15.13%)
Monthly mean temperature (Degree Celsius)	15.718 (8.784)	18.477 (7.632)	19.110 (8.019)	23.383 (5.632)	19.301 (8.062)
Monthly total precipitation (Millimeter)	60.070 (38.967)	101.371 (76.937)	92.940 (69.939)	123.509 (82.718)	93.281 (72.499)

Notes: Columns 1-4 are four country groups divided by the lower quartile, median, and the upper quartile in terms of the agricultural ratio, where column 1 represents the least agriculture-dependent countries, and column 4 includes the most agriculture-dependent countries. Colum 5 represents all the countries. Standard deviations are in parenthesis.

Table 2. Climate and international migration: the reduced-form regression

	Model 1	Model 2	Model 3
Temperature	-0.000	0.001	0.004
	(0.006)	(0.006)	(0.006)
Temperature × Agriculture	0.024*	0.048***	0.047***
	(0.012)	(0.013)	(0.013)
Precipitation		0.000	0.000
		(0.000)	(0.000)
Precipitation × Agriculture		0.001***	0.001***
		(0.000)	(0.000)
GDP variables	No	No	Yes
Country-pair FE	Yes	Yes	Yes
Origin country-specific linear time trend	Yes	Yes	Yes
Observations	92,137	92,137	92,137
Number of origin countries	160	160	160
R^2 (within)	0.1866	0.1868	0.1904
Temperature effect in agriculture-dependent countries	0.024**	0.049***	0.051***
	(0.011)	(0.012)	(0.012)

Notes: Dependent variable is the natural logarithm of migration rate. Agriculture is defined as a dummy based on origin countries, where top 25% agriculture-dependent countries are assigned with "1", and the rest of countries are assigned with "0".

Robust standard errors clustered by country-pairs are reported in parentheses.
*** p<0.01; ** p<0.05; * p<0.1.

Table 3. Robustness checks for the reduced-form model

	Agriculture-dependent countries		
	(1)	(2)	(3)
Baseline specification			
	0.024**	0.047***	0.055***
	(0.012)	(0.013)	(0.014)
Panel A: Controlling for lagged one year temperature and precipitation			
	0.014	0.033**	0.043***
	(0.011)	(0.013)	(0.014)
Panel B: Controlling for lagged temperature and precipitation (up to five years)			
	0.011	0.028**	0.040***
	(0.012)	(0.014)	(0.014)
Panel C: Controlling for lagged migration stock			
	0.014	0.039**	0.051***
	(0.015)	(0.017)	(0.018)
Panel D: Controlling for lagged one year migration rate			
	0.016*	0.025**	0.029***
	(0.009)	(0.010)	(0.011)
Panel E: Controlling for origin country-specific quadratic time trend			
	0.019*	0.035***	0.047***
	(0.011)	(0.013)	(0.013)
Panel F: Controlling for both origin and destination country fixed effects			
	0.020	0.047***	0.048***
	(0.015)	(0.018)	(0.019)
Panel G: Regressions weighted by origin country population			
	0.010	0.026	0.046**
	(0.018)	(0.020)	(0.020)
Panel H: Using the natural log of migration flows as dependent variable			
	0.024**	0.046***	0.053***
	(0.012)	(0.013)	(0.014)
Panel I: Dropping observations with top 5% country pairs by migration flows			
	0.024**	0.050***	0.059***
	(0.012)	(0.014)	(0.014)
Panel J: Dropping observations with top 1% country pairs by migration flows			
	0.025**	0.049***	0.057***
	(0.012)	(0.013)	(0.014)
Panel K: Dropping observations with zero migration flows			
	0.022*	0.045***	0.054***
	(0.012)	(0.015)	(0.015)

Notes: The coefficients shown are the interaction term of contemporaneous temperature with agricultural dependence. Each column represents different definitions of agriculture-dependent countries used in the interaction term: (1) agricultural dependence=1 for top 33% countries with the highest agricultural ratio, and agricultural dependence=0 for other countries. (2) top 25%. (3) top 20%.

In Panel F, controls variables such as distance, language, colonial past, common border are included the model, since these country pair variables are no longer controlled for without country-pair fixed effects.

Robust standard errors clustered by country-pairs are reported in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Table 4. Temperature effects by destination countries

	(1)	(2)	(3)	(4)
Temperature	-0.003	-0.004	0.003	-0.002
	(0.015)	(0.012)	(0.010)	(0.009)
Temperature × Agriculture	0.017	0.028	0.012	0.057**
	(0.018)	(0.025)	(0.025)	(0.025)
Precipitation variables	Yes	Yes	Yes	Yes
Include GDP variables	Yes	Yes	Yes	Yes
Country-pair FE	Yes	Yes	Yes	Yes
Country-specific linear time trend	Yes	Yes	Yes	Yes
Observations	13,800	22,649	25,664	30,024
Number of origin countries	160	160	160	160
Adjusted R-squared	0.289	0.246	0.246	0.240

Notes: The sample are divided into four destination country groups by the lower quartile, median, and the upper quartile in terms of the size of migration flows from each origin country, where column (1) represents destination countries with small migration flow from each origin country, and column (4) represents destination countries with large migration flow from each origin country.

Robust standard errors clustered by country-pairs are reported in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 5. The first stage results: Cereal yields and climate

	(1)	(2)	(3)	(4)
Temperature	-0.010	-0.047***	-0.025**	-0.033**
	(0.017)	(0.011)	(0.010)	(0.014)
Precipitation	-0.000	0.000	0.000	0.001*
	(0.001)	(0.000)	(0.000)	(0.000)
Number of Observations	1,118	1,086	1,031	1,092
Number of Countries	40	39	38	38
Adjusted R^2	0.323	0.471	0.373	0.488
F statistics	0.24	9.84	4.00	5.16
Prob > F	0.7877	0.0004	0.0268	0.0105

Notes: The natural logarithm of cereal yields is the dependent variable in the first stage. Columns 1-4 are four country groups divided by the lower quartile, median, and the upper quartile in terms of the agricultural ratio, where column (1) represents the least agriculture-dependent countries, and column (4) represents more agriculture-dependent countries.

Robust standard errors clustered by country are reported in parentheses.
*** p<0.01; ** p<0.05; * p<0.1

Table 6. The second stage results: International migration and cereal yields

	(1)	(2)	(3)	(4)
	Panel A: FE-OLS			
Log of origin cereal yields	0.008	-0.210*	-0.174	-0.456**
	(0.054)	(0.105)	(0.108)	(0.173)
	Panel B: FE-2SLS			
Log of origin cereal yields	0.760	1.604	-2.131	-1.607**
	(2.165)	(1.030)	(1.443)	(0.713)
Country FE	Yes	Yes	Yes	Yes
Country-specific time trend	Yes	Yes	Yes	Yes
Number of Countries	40	39	38	38
Observations	1,118	1,086	1,031	1,092

Notes: The natural log of total out-migration ratio is dependent variable in the second stage. Columns 1-4 are four country groups divided by the lower quartile, median, and the upper quartile in terms of the agricultural ratio, where column (1) represents the least agriculture-dependent countries, and column (4) represents more agriculture-dependent countries.

Robust standard errors clustered by country are reported in parentheses.
*** p<0.01; ** p<0.05; * p<0.1

Table 7. Robustness checks for the 2SLS results

	First stage F statistic (*Prob > F*)	Second stage coefficients	
		2SLS	LIML
Baseline specification			
	5.16	-1.607**	-1.607**
	(*0.0105*)	(0.713)	(0.713)
Panel A: Using only temperature as instrument			
	8.82	-1.613**	-1.613**
	(*0.0052*)	(0.732)	(0.732)
Panel B: Using only precipitation as instrument			
	8.04	-1.594*	-1.594*
	(*0.0074*)	(0.970)	(0.970)
Panel C: Using lagged yield and climate variables			
	4.60	-1.981**	-2.040**
	(*0.0164*)	(0.957)	(1.001)
Panel D: also controlling for origin country GDP per capita			
	5.19	-1.390**	-1.394**
	(*0.0099*)	(0.700)	(0.700)
Panel E: Using the natural log of migration flows			
	5.16	-1.662**	-1.662**
	(*0.0105*)	(0.712)	(0.712)
Panel F: Using top 33% agricultural countries			
	5.79	-1.731**	-1.732**
	(*0.0054*)	(0.771)	(0.772)
Panel G: Using top 20% agriculture countries			
	5.45	-1.606**	-1.628**
	(*0.0096*)	(0.679)	(0.694)

Notes: Panels A – E are based on the top 25% agricultural countries.

Robust standard errors clustered by country-pairs are reported in parentheses.
*** p<0.01; ** p<0.05; * p<0.1

Appendix Tables:

Appendix Table A1: Country-Year coverage migration flows
Columns: Destination Countries
Rows: Year
Cell: numbers of source countries, for which we have some observations on the number of migrants entering a given destination in a particular year

Dest	AUS	AUT	BEL	BGR	CAN	CHE	CHL	CYP	CZE	DEU	DNK	ESP	EST	FIN	FRA	GBR	GRC	HRV	HUN	IRL	ISL	ISR	ITA	JPN	KOR	LTU	LUX	LVA	MEX	MLT	NLD	NOR	NZL
Year																																	
2010	208	190			217	198			135	193	203	113	212	183					144	208	179					204	141				194	213	212
2009	205	190	184		214	194	140		141	193	203	113	209	183		26			139	209	178	44	188	201	58	205	141	209	128		198	202	212
2008	204	190	182	207	214	194	140	209	143	194	203	113	208	183	120	21		208	142	208	178	44	187	198	57	204	146	207	126		195	202	213
2007	206	190	93	190	214	194	140	190	147	193	203	113	190	183	124	19	191	190	128	2	178	44	181	197	28	190	142	190	126	190	197	202	213
2006	206	190	96		214	194	140	190	142	193	202	108	190	183	120	34	190	190	133	2	178	44	182	195	10	190	139	191			193	202	213
2005	203	190	85		214	194	140	189	142	191	203	66	190	183	107	114			121	2	178	44	185	10	10	189	137	189			187	202	213
2004	203	190	71		214	194	140	189	146	191	203	57	190	183	107	109		189	108	2	178	44	183	10	10	189	135	189			193	202	213
2003	201	189	70		214	195	140	189	142	191	203	57		183	127	107		189	121	2	178	44	180	10	10	189	127	189			191	202	213
2002	198	189	70		214	194		187	141	191	203	57		183	128	99		187	110	2	178	44	182	10	10	188	123	187			198	192	213
2001	198	189	70		214	194		131	115	84	203	57		183	130	106		187	117	2	178	44	181	10	10	195	116	195		187	197	192	213
2000	200	189	70		214	180		195	110	83	203	59		183	129	111			118	2	178	44	182	15	10	195	124	195		131	197	192	213
1999	198	189	70		214	180			108	193	203	58	188	183	118	110		187	114	2	178	44	181	15		195	123	195		131	191	192	213
1998	193	189	70		214	180		131	122	193	203	59	188	183	117	116	188	129	114	2	178	44	182	14		195	120	188		131	191	192	213
1997	192	189	55		214	179			111	193	203	39		183	118	48	183		114	2	178		179	14			110				194	192	213
1996	195	189	55		214	176			114	193	203	58		183	118	52	205		116	2	178		178	14			108				191	191	213
1995	187		55		214	176			117	193	203	39		183	118	54	203		117	2	178		48	15			110				187	192	213
1994	186		55		214	179			106	193	203	39		183	118	27	205		119	2	178		32	14			103				186	192	213
1993	180		48		214	178			97	193	203	39		183		39	205		106	2	178		32	14			99				185	192	213
1992	182		48		214	174				189	203	45		183		45	205		111	2	178		32	14			105				174	191	213
1991	171		48		213	158				172	203	42		183		49	206		104	2	178		32	11			95				160	191	213
1990	168		48		213	156				44	203	42		183		38	200		102	2	178		32	12			100				163	190	213
1989	155		48		213	154				105	203	42		183		31			97	2	178		32	11			93				164	192	213
1988	150		25		213	159				105	203	42		183		38			100	2	178		32	11			94				158	192	213
1987	159		27		213	155				105	203			183		29			99	2	178		32	7			93				161	192	213
1986	153		27		213	154				105	203			183		33			103		178		32	7								191	213
1985	155		27		213	154				105	203			183		35			95		18		32	7								116	213
1984	154		27		213	151				105	203			183							18											205	213
1983	166		27		213	152				105	203			183							18											205	213
1982	161		27		213	154				105	203										18											205	213
1981			27		213	154				105	203										18											205	213
1980			27		213					105	203																					205	213
	AUS	AUT	BEL	BGR	CAN	CHE	CHL	CYP	CZE	DEU	DNK	ESP	EST	FIN	FRA	GBR	GRC	HRV	HUN	IRL	ISL	ISR	ITA	JPN	KOR	LTU	LUX	LVA	MEX	MLT	NLD	NOR	NZL

Appendix Table A2: Inflows of Foreign Population: Definitions and Sources

Migration flows to:	***Definition of "foreigner" based on***	***Source***
Australia	Country of Birth	Permanent and long term arrivals, Government of Australia, DIMA, Dept. of Immigration and Multicultural Affairs http://www.immi.gov.au/media/statistics/index.htm
Austria	Citizenship	Population register, Statistik Austria (1997 to 2002), Wanderungsstatistik 1996-2001, Vienna
Belgium	Citizenship	Population register. Institut National de Statistique.
Bulgaria	Citizenship	Eurostat.
Canada	Country of Birth	Issues of permanent residence permit. Statistics Canada – Citizenship and Immigration Statistics. *Flow is defined as a sum of foreign students, foreign workers and permanent residents.* http://www.cic.gc.ca/english/resources/statistics/facts2009/glossary.asp
Chile	Citizenship	OECD Source International Migration data
Cyprus	Citizenship	Eurostat.
Czech Rep.	Citizenship	Permanent residence permit and long-term visa, Population register, Czech Statistical Office
Denmark	Citizenship	Population register. Danmarks Statistics
Estonia	Citizenship	Eurostat
Finland	Citizenship	Population register. Finish central statistical office
France	Citizenship	Statistics on long-term migration produced by the 'Institut national d'études démographiques (INED)' on the base on residence permit data (validity at least 1 year) transmitted by the Ministry of Interior.
Germany	Citizenship	Population register. Statistisches Bundesamt
Greece	Citizenship	Labour force survey. National Statistical Service of Greece 2006-2007 Eurostat
Hungary	Citizenship	Residence permits, National Hungary statistical office.
Iceland	Citizenship	Population register. Hagstofa Islands national statistical office.
Ireland	Country of Birth	Labour Force Survey. Central Statistical Office. Very aggregate, only very few individual origins.
Israel	Citizenship	OECD Source International Migration data
Italy	Citizenship	Residence Permits. ISTAT
Japan	Citizenship	Years 1988-2005: Permanent and long-term permits. Register of Foreigners, Ministry of Justice, Office of Immigration. Years 2006-2008: Permanent and long-term permits. OECD Source International Migration data
Korea	Citizenship	OECD Source International Migration data
Latvia	Citizenship	Eurostat
Lithuania	Citizenship	Eurostat
Luxembourg	Citizenship	Population register, Statistical Office Luxembourg
Malta	Citizenship	Eurostat.
Mexico	Citizenship	OECD Source International Migration data
Netherlands	Country of Birth	Population register, CBS
New Zealand	Last Permanent Residence	Permanent and Long-term ARRIVALS (Annual – Dec) Census, Statistics New Zealand
Norway	1979-1984 Country of Origin 1985-2009 Citizenship	Population register, Statistics Norway
Poland	Country of Origin	Administrative systems (PESEL, POBYT), statistical surveys (LFS, EU-SILC, Population censuses). Central Statistical Office of Poland
Portugal	Citizenship	Residence Permit, Ministry of Interior.

Romania	Citizenship	Eurostat.
Russian Fed.	Citizenship	OECD Source International Migration data.
Slovak rep.	Country of Origin	Permanent residence permit and long-term visa, Slovak Statistical Office
Slovenia	Citizenship	Data for 1996-1997 taken from UN migration data. 1998 – 2009 Eurostat.
Spain	Country of Origin	Residence Permit, Ministry of Interior
Sweden	Citizenship	Population register, Statistics Sweden
Switzerland	Citizenship	Register of Foreigners, Federal Foreign Office of Switzerland
Turkey	Citizenship	OECD Source International Migration data
United Kingdom	Citizenship	Residence permits for at least 12 months. IPS - office for national statistics, and EUROSTAT
United States	Country of Birth	US Census Bureau Current Population Survey (CPS); U.S. Department of Homeland Security: *Yearbook of Immigration Statistics.* Persons obtaining Legal Permanent Resident Status by Region and Country of birth www.dhs.gov/ximgtn/statistics/publications/LPR06.shtm)

1