The Impact of Air Pollution on Internal Migration in the Czech Republic

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Abstract
This paper focuses on analyses of determinants of internal (interregional) migration in the Czech Republic. In previous studies, there are considered main economic determinants, for example wages, unemployment and vacancy rates as important determinants of migration. For approximation of migration costs have been used especially distance and neighbourhood of districts (regions). In my study I posit that environmental pollution can play an increasingly important role in driving migration. It is possible to say, that breathing of polluted air should destroy human health, so pollution can act as a part of living costs (negative externality) and thus it can act as a "push" factor for people to migrate. I shed some light on the determinants by using data on inter-regional migration in the Czech Republic for years 1994-2011.

Key words
Migration, district, pollution, economic determinants

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1 Introduction and Motivation

Migration is not new in the human history. There were always many factors forcing or attracting people to migration throughout the history of mankind, and there will always exist some factors influencing migration decisions. Large part of migration research has focused on learning about "typical" migration determinants. These include e. g. 1) economic differences, such as wages, unemployment and vacancy rates in destinations and origins, and 2) costs of migration usually proxied by distance, sharing a common border, existence of migrants diaspora and diverse cultural and linguistic distances between countries or regions, and 3) political push factors, such as wars or lack of political and civil liberties at origins (Karemera, 1997).

Recently, the migration literature has paid more and more attention to climatic and environmental factors, such as sea level rise, environmental degradation, weather-related crop failures, and extreme weather events (Hugo, 1996; Myers, 2002; Warner et al., 2009; Piguet et al., 2011; Gray and Mueller, 2012). Many studies found a significant influence of climate on human migration. For instance Cai, Feng, Pytlikova and Oppenheimer (2004) using international migration data for 42 destinations from all origins for ears 1980-2010, find that weather variability, in particular temperature increases, influence international migration, but only migration from agriculturally dependent countries, which is consistent with the widely-documented adverse impact of temperature on agricultural productivity. Using unbalanced panel data, Barrios et al. (2006) found that rainfall is likely to affect rural-to-urban migration in sub-Saharan Africa. Feng et al. (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 has a modest effect. Using a country-level panel data of sub-Saharan Africa, Marchiori et al. (2012) found that weather anomalies increase internal and international migration through both amenity and economic geography channels. Mueller et al. (2014) found that flooding has modest impacts on migration, while heat stress increases the long-term migration in Pakistan.

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.

One can argue that one of the environmental factors likely affecting people's migration choices is environmental pollution. Nowadays people in developed countries (and not only) are concern by healthy lifestyle. Living in polluted areas affect, especially in big cities, where is concentrated traffic and /or in industrial areas with significantly polluting factories may negatively affect people's health and living standards. Thus in this paper we posit that environmental pollution can be an important push factors affecting migration. To the best of our knowledge this is the first study to deal with the topic and to try the effects of air pollution on decisions of potential migrants. We hypothesise, that living in polluted environment causes

a cost to the people. People living in contaminated areas usually suffer from various illnesses, they must pay higher expenditures on health care; they are more likely to take a sick leave than people living in clean environments. It can motivate them to migrate to more clean regions. Alternatively, polluted environments can be seen as negative amenities and we can posit, that living in polluted environment is simply uncomfortable for some inhabitants, they would like to live and raise their children in environmentally clean areas. This might be true especially for more educated people's health and living standards. We test those hypotheses using regional data from the Czech Republic over a period of years 2004-2011.

There are a number of pollutants discharged into the atmosphere that are known to affect human health. For instance, nitrogen oxides (NO_x) can have adverse effects on human health, especially at higher concentrations, which does not normally occur in the atmosphere. Inhalation of high concentrations of this gases leads to serious health problems and can even cause death. It is believed that nitrogen oxides bind to the blood pigment and impair the transmission of oxygen from the lungs to the tissues. Some indications suggest that nitrogen oxides have a role in the development of cancer. Inhalation of high concentrations of nitrogen oxides irritates the airways. Overall it is necessary to say, that these oxides are substances with a wide range of negative health impacts and impacts especially on the global ecosystem. Main source of NO_x is combustion of the noble fuels (especially using vehicles); however there are also normal biological processes, which produces this gas, such as oxidation of nitrogen discharges in the atmosphere (lightning) and action of microorganisms (MZP CR, 2014). Other substance, which has negative impact on human health, is sulphur dioxide (SO_2). Sulphur dioxide irritates eyes and upper respiratory tract. At higher concentrations increases respiratory morbidity in susceptible adults and children. The concentration of 0.5 $mg \cdot m^{-3}$ leads to increase in mortality at elderly and chronically ill people. Significantly vulnerable people are especially asthmatics, who are the most sensitive to action of sulphur oxides. Contact with higher concentrations of SO_2 cause health symptoms as eye damage; damage of the respiratory system (coughing, breathing more difficult) and at very high concentrations fluid in the lungs (edema). Main sources of these gas emissions are production of electric and thermal energy, petroleum refineries, vehicles and metal processing. Sulphur oxides plays also an important role in creation of Sulfurous smog - so called "London type smog". Third important common pollutant is carbon monoxide (CO). Small concentrations of carbon monoxide, which occur normally in the atmosphere, e. g. in the cities, can cause serious health problems particularly to persons suffering from cardiovascular diseases (e. g. angina pectoris). Prolonged exposure to higher concentrations of carbon monoxide in the air can bring different problems such as reduced work performance, reduced manual dexterity, impaired ability to study and problems with solving complicated tasks. Exposure to small doses of CO during the pregnancy may cause lower birth weight of newborns. Further, particles of airborne dust are among the common pollutants. Their dangerousness depends on their size. The most dangerous are the smallest particles, which can settle in the lungs. Dust contains also carcinogenic compounds. Inhalation of these substances mainly harms the cardiovascular and pulmonary system. Prolonged exposure reduces life expectancy and increases infant mortality. It can cause chronic bronchitis and chronic pulmonary disease. People, who live in polluted environment by these substances, are threatened by development

of cancer with quite high probability (MZP CR[1], 2014).Together with the economic determinants, pollution of environment (in this case air pollution) can affect people's decision to migrate. In this paper we analyse the role of environmental pollution on migration using inter-regional migration dataset.

2 Economic Theory and Previous Research

There is relatively sizable literature on determinants of migration. Early literature suggests that the most important factor, which influence migration flows is income maximization (Hicks, 1932; Sjastaad, 1962, Harris and Todaro, 1970, Borjas, 1989; Mayda, 2010). Potential migrant compares revenues in origin region with revenues in region of destination. This person takes in consideration also the costs of migration (Harris and Todaro, 1970). If total expended revenues in destination region will be higher than expended revenues in origin plus migration costs, potential migrant migrate to new destination. Migration costs consist of direct costs and psychological costs (it can be e. g. loss of friends and fatherland) (Massey, 1993). Further, migration decisions do not depend only on individual person, but they are often decision of the entire household and family, thus it depends also on maximization of future incomes of all members of the family (Stark and Yitzhaki, 1985). Quite important is distance between origin and destination region. With increasing distance between regions decrease probability of migration, because potential migrant has to spend higher expenditures.

The determinants of migration are often analysed within the neoclassical gravity spatial equilibrium framework. The amount of income and economic level has a positive impact on migration flows, if there is possibility to achieve higher economic level in the destination country (pull effect). Conversely, if the economic level increases in their origin country (region), it has a negative effect on migration. Unemployment rate acts as push factor. High rate of unemployment in source region motivate potential migrants to remove to new destination. Vice versa, high unemployment rate in region of the destination decreases propensity to migrate into this region. We can say that the push factors, which residents "force" to leave the home economy, have mainly economic, social and political character. Among the pull factors are beyond the aforementioned ranked the quality of living conditions and self-fulfilment. This hypothesis tested Karemera, et al. (1997) on the sample of international migration to North America. It is usually called *push and pull* theory of migration.

There were performed some studies on interregional migration in Czech Republic. Pytlikova (2006) founded, that wages, respectively their differentials, are key driving force in interregional migration between districts in the Czech Republic. However, unemployment rate does not play important role in formation of interregional migration. It could be caused by dramatically growth of unemployment rate in observed time period. Another explanation can be existence of generous systems of social security, which did not stimulate unemployed people to remove to another region and get new job there. Distance between two districts had

[1] Ministry of Environment of the Czech Republic.

significant effect on migration, so there was confirmed hypothesis, that with longer distance migration flows decrease. Fidrmuc and Huber (2007) investigated willingness to migrate of Czech citizens. They found out, that the most important determinant of migration are age of potential migrant (younger potential migrant has higher propensity to migrate), income and ownership of house or flat. Their results suggests that persons owning a family house are substantially less willing to migrate and that the willingness to migrate and decreases with income. This implies that housing market imperfections, high shares of owner occupied housing and low migration incentives for the medium income groups are an important component in explaining low migration. On average, persons experiencing longer unemployment are not less willing to migrate. In their study, they distinguish population according by gender and education. It is possible to say, that men and higher educated people are more willing to migrate. They calculated also with emissions, but this factor has not high significance.

In this paper we analyse determinants of inter-regional migration in the Czech Republic with a special focus on the role of environmental pollution in driving regional migration.

3 Data and models

Data

In the analysis are used data, which was collected from outputs of Czech Statistical Office. It covers 18 years period since 1994 to 2011. Czech Statistical office provides annual migration register, where are captured migration flows from region *i* to region *j*, however, there are not observed international migrants in this tables. Area of the Czech Republic consists of 77 districts. For making analysis of internal migration flows is more preferable to use district as a unit, because regions[2] are larger and do not allow us to capture detailed migration flows. In the Czech Republic is migration defined as a movement of population with registration of the new residence in aim destination, but not all migrants register their new residence. There should be problem with undervaluation of migration flow however; long-tem migration is usually associated with registering of new residence. In empirical analyses of migration flows and their determinants are used also data regarding wages, number of unemployed people, unemployment rates, vacancies, population and urbanization. All of them are published by Czech Statistical Office. There is one important problem, data on wages are published only to year 2005. Czech Ministry of Labour and Social Affairs and Czech Statistical office did not allowed us to calculate with data from 2005 to 2012 due to poor statistical power (data 2005-2012 exists, but they are non-public). It shorts observed time period, but in regressions, wages are usually high correlated with rate of unemployment, so we are able to estimate models during all period without wages. For approximation of migration costs is calculated with distance between pair of districts (their main cities). This evidence was gained from Czech Railway´s information service. The most variable in the monitored period was the number of migrants from districts *i* to districts *j*. This variability also continued to grow, but in recent

[2] In Czech Republic called „kraj“.

years there has been a slight decrease in disparities between the districts. Significant fluctuations differences between districts were noted in vacancies. This is probably due to differences in economic level between districts. For other variables, there were recorded almost constant variability and it leads to persistence of existing differences between Czech districts. It should be noted, that the differences between districts grew during the economic crisis. As mentioned, this paper is primarily focused on impact of air pollution on internal migration flows. Evidence about emissions of harmful gases and airborne dust particles are published annually also by Czech Statistical office (obtained from Czech Hydro Meteorological Office). Especially, North Moravia, Silesia and bigger agglomerations are affected by air pollution in long term.

Models

I base my empirical model on the human capital theoretical framework (Sjastaad, 1962), applied for instance in Adsera and Pytlikova (forthcoming). My preferred empirical model specification can be written as:

$$lnmij1_t = \gamma_1 + \gamma_2 lnunemplratej1_{t-1} + \gamma_3 lnvacanratej1_{t-1} + \gamma_4 lnunemplratei1_{t-1} + \gamma_5 lndistance + \gamma_6 neighbour + \gamma_7 lnDUSTi_{t-1} + \gamma_8 lnSO2i_{t-1} + \gamma_9 lnNOXi_{t-1} + \gamma_{10} lnCOi_{t-1} + \varepsilon_{jit}. \quad (1)$$

Where:

$lnmij1_t$ is natural logarithm of migration rate between destination (*j*) and source (*i*) district at time *t* (dependent variable), $lnunemplratej1_{t-1}$ is 1 year lagged natural logarithm of unemployment rate in destination district, $lnvacanratej1_{t-1}$ is 1 year lagged natural logarithm of vacancy rate in destination district (per 1000 inhabitants), $lnunemplratei1_{t-1}$ is 1 year lagged natural logarithm of unemployment rate in origin district (per 1000 inhabitants), $lndistance$ is natural logarithm of distance between district i and j, $neighbour$ is dummy variable for neighbouring districts i and j, $lnDUSTi_{t-1}$ is 1 year lagged natural logarithm of airborn dust in destination district, $lnSO2i_{t-1}$ is 1 year lagged natural logarithm of SO_2 emissions in destination district, $lnNOXi_{t-1}$ is 1 year lagged natural logarithm of NO_x in destination region, $lnCOi_{t-1}$ 1 year lagged natural logarithm of CO emissions in destination district, $\gamma_1 - \gamma_{10}$ are regression coefficients and ε_{jit} is residual component.

However, it is basic model, where are not contained population characteristic for catch of impact of bigger agglomerations. So, there are used two independent variables – population an urbanization rate. Model should be rewritten as:

$$lnmij1_t = \gamma_1 + \gamma_2 lnunemplratej1_{t-1} + \gamma_3 lnvacanratej1_{t-1} + \gamma_4 lnunemplratei1_{t-1} + \gamma_5 lnpopi1_{t-1} + \gamma_6 lnpopj1_{t-1} + \gamma_7 lnurbani1_{t-1} + \gamma_8 lnurbanj1_{t-1} + \gamma_9 lndistance + \gamma_{10} neighbour + \gamma_{11} lnDUSTi_{t-1} + \gamma_{12} lnSO2i_{t-1} + \gamma_{13} lnNOXi_{t-1} + \gamma_{14} lnCOi_{t-1} + \varepsilon_{jit}. \quad (2)$$

This model contains new four independent variables:

$lnpopi1_{t-1}$ is lagged natural logarithm of population in origin district, $lnpopj1_{t-1}$ is lagged natural logarithm of population in destination district, $lnurbani1_{t-1}$ is lagged natural logarithm of urbanization rate in origin district, $lnurbanj1_{t-1}$ is lagged natural logarithm of urbanization rate in destination district.

According economic theory of migration is important to estimate migration models with independent variable "income". But these models are without this variable. We are able to estimate models without this variable, because wage and unemployment rate are correlated. Third "type" of model contains new variable wage, but it is important to note, that using this variable will shorten number of observations, because wage data are on disposal only from 1994 to 2005. New model should be written:

$$lnmij1_t = \gamma_1 + \gamma_2 lnunemplratej1_{t-1} + \gamma_3 lnvacanratej1_{t-1} + \gamma_4 lnwj1_{t-1} + \gamma_5 lnunemplratei1_{t-1} + \gamma_6 lnwi1_{t-1} + \gamma_7 lnpopi1_{t-1} + \gamma_8 lnpopj1_{t-1} + \gamma_9 lnurbani1_{t-1} + \gamma_{10} lnurbanj1_{t-1} + \gamma_{11} lndistance + \gamma_{12} neighbour + \gamma_{13} lnDUSTi_{t-1} + \gamma_{14} lnSO2i_{t-1} + \gamma_{15} lnNOXi_{t-1} + \gamma_{16} lnCOi_{t-1} + \varepsilon_{jit} \quad (3)$$

There are also new variables: $lnwj1_{t-1}$ is lagged natural logarithm of wages in destination district and $lnwi1_{t-1}$ is lagged natural logarithm of wages in origin district.

For estimating models in my paper I use the OLS method with robust standard errors, because it is necessary to eliminate problems with heteroskedasticity. Further, it is plausible that there are a number of unobservable destination and origin region effects that affect migration. Therefore I estimate my empirical models also with regional fixed effects (FE).

We suppose, that unemployment rate regression coefficient in destination will acquire negative values, because unemployment rate in destination usually demotivates people to remove into this region. Vacancy rate in destination conversely attract potential migrants. Increasing number of vacancies in destination district attracts potential migrants, because there is higher probability to find a job. Wages in destination also play a role of pull factor in making migration decision, so we suppose that its regression coefficient should have positive value. Conversely, unemployment rate in origin district irritates local inhabitants and should push them from their origin region so we suppose positive values of regression coefficients.

Other factor is wage in origin region. With higher wage in origin, people are not motivated to search for a new district, where their wage should be higher (we suppose negative values of

regression coefficients). Population characteristics are in our models used for catch of agglomeration effects. Models contain two types of these variables - population in origin and destination district and urbanization rate in origin and destination district. It is possible to say, that people usually migrate to regions with higher number of inhabitants and from rural to the cities, where are usually better amenities and better working opportunities.

Distance and neighbour are usually used for approximation of costs in migration models. It is necessary to say, that with longer distance, costs increase and we suppose negative value at this coefficient. On migration to neighbouring district, potential migrant should not pay so high costs, thus there is possibility to suppose positive values. As mentioned above, pollution can also play a role of costs. In this model is included pollution in source districts and it should have a positive effect on migration flows. Especially more educated and better paid persons want to live in cleaner environment and they are "pushed" from origin district.

4 Analyses and Results

All columns of Table 1 show estimations of empirical migration models between districts in Czech Republic. First, there were estimated models without fixed effects. In all models were typical migration determinants statistically significant and almost of them confirmed hypothesis about their behaviour. As mentioned, there were added other independent variables, which should to catch agglomeration effect. There were also confirmed hypothesis. People almost migrate from less populated districts to densely populated areas. We can say, that it persists trend, when people migrate from "rural" districts to more urbanised regions. There is conflict between hypothesis about population characteristics and pollution hypothesis. More urbanised and populated regions has always higher rate of pollution, however they also provide better economic conditions for living (amenities, better work opportunities). It can cause negative sign at pollution variables regression coefficients. There were added wages into this model. We also confirm economic theory and it is possible to note, that wages (incomes) play an important role in shaping migration flows between districts in the Czech Republic.

The highest impact on interregional migration in Czech Republic traditionally has a distance. It means that with longer distance decrease a propensity to migrate (due to higher costs) and it confirms economic theory. So, in making migration decisions, play the most important role migration costs. It confirms also variable neighbour – people do not have to spend so high costs, if they migrate to neighbouring district. Probably, due to are migration flows between districts in Czech Republic so low.

There were used also fixed effects in estimating migration models. As mentioned, it serves for detecting unobserved factors, which should have an impact for migration. In the regressions using destination and origin region fixed effects the R square increases, so there are surely some unobserved effects driving migration between districts in Czech Republic. We can observe that the most influence has lnpopj1 – it can cause capital Prague, because there lead up the highest migration flows. You can see, that unemployment rate does not play an

important role in shaping migration. It is probably caused by better motivation with wages and vacancies. **We have to note, that third and sixth model have lower number of observations, due to availability of wages data (to 2005).** However, this paper is focused especially on pollution in shaping migration flows. Almost of regression coefficients has negative sign, so there were not confirmed hypothesis. In my opinion it is caused by preferring typical economic determinants against air pollution and human health.

Table 1: Regression models of migration flows (1994-2011)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	lnmij1	lnmij1	lnmij1	lnmij1	lnmij1	lnmij1
lnunemplratej1	-0.091***	-0.120***	-0.087***	0.045***	0.026**	-0.014
	(0.020)	(0.012)	(0.013)	(0.012)	(0.011)	(0.014)
lnvacanratej1	0.097***	0.122***	0.095***	0.089***	0.087***	0.048***
	(0.008)	(0.007)	(0.009)	(0.005)	(0.005)	(0.007)
lnunemplratei1	0.201***	0.143***	0.067***	-0.042***	-0.010	-0.042***
	(0.015)	(0.012)	(0.013)	(0.011)	(0.011)	(0.013)
lndistance	-1.071***	-1.064***	-1.023***	-1.108***	-1.108***	-1.108***
	(0.019)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
neighbour	0.960***	1.018***	1.068***	1.002***	1.002***	0.996***
	(0.051)	(0.045)	(0.045)	(0.044)	(0.044)	(0.044)
lnDUSTi	0.005	-0.055***	0.034***	-0.091***	-0.079***	-0.024***
	(0.014)	(0.011)	(0.011)	(0.008)	(0.007)	(0.009)
lnSO2i	0.036***	-0.090***	-0.073***	-0.000	-0.007	0.024**
	(0.013)	(0.011)	(0.012)	(0.009)	(0.009)	(0.010)
lnNOXi	-0.037***	0.061***	0.038***	-0.019**	0.011	-0.032**
	(0.012)	(0.009)	(0.011)	(0.009)	(0.009)	(0.012)
lnCOi	-0.059***	0.015	-0.002	-0.065***	-0.064***	-0.031***
	(0.013)	(0.010)	(0.010)	(0.010)	(0.009)	(0.011)
lnwj1			0.668***			0.629***
			(0.066)			(0.076)
lnwi1			-0.330***			-0.307***
			(0.061)			(0.075)
lnpopi1		-0.346***	-0.356***		0.283***	-0.040
		(0.018)	(0.019)		(0.068)	(0.152)
lnpopj1		0.662***	0.576***		2.103***	2.218***
		(0.017)	(0.018)		(0.063)	(0.171)
lnurbani1		0.794***	0.718***		-0.150*	-0.165
		(0.033)	(0.034)		(0.086)	(0.123)
lnurbanj1		0.397***	0.367***		-0.195**	-0.208*
		(0.028)	(0.030)		(0.085)	(0.124)
FE origin				YES	YES	YES
FE destination				YES	YES	YES
Constant	2.418***	-6.083***	-7.807***	5.810***	-26.058***	-26.299***
	(0.111)	(0.304)	(0.417)	(0.093)	(1.428)	(3.271)
Observations	93,278	93,278	64,032	93,278	93,278	64,032
Adjusted R-squared	0.525	0.645	0.639	0.708	0.711	0.703

Source: own calculations.

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

5 Conclusion

There are plenty of studies on determinants of migration, but to the best oh my knowledge there is no much on the role of environmental pollution that can be seen as a negative externality. It can cause higher living expenditures for inhabitants of regions, where they live. Main pollutants in Czech Republic are airborn dust, SO_2, NO_x and CO. As mentioned, they can significantly damage human health. In this case, air pollution should cause migration flows (emigration from polluted districts). However, from our first analyses we cannot confirm this hypothesis for most of the pollutants considered. This might be because environmentally polluted areas are also likely correlated with economic and cultural outcomes, which I tried to cover, but unfortunately e.g. wage data are not available beyond yea 2005.

The most important role in shaping migration plays costs of migration. The strongest impacts (in comparison with other types of costs) have a distance. Other types of costs (including air pollution) are also important in explanation of migration flows, but their impact is not so high. Wages, distance and neighbour are quite strong determinant in creating migration between districts. It corresponds to the economic theory of migration.

We can observe that population in Czech Republic prefer "economic" reasons of migration against their health and environmental conditions. Probably there are some households, which migrate due to these conditions, but the effect os not so significant for the Czech Republic.

In the next version of the paper, I would like to disentangle the role of economic factors and the environment, in particular I would like to explore some exogenous shocks such as closing of large pollutants in certain regions.

Further interesting hypotheses to be considered in the future work is to test selectivity in migration with respect to environmental pollution. In particular, I would like to test whether pollution act as a migration push especially for the more educated and better-paid persons. This is something I would like to explore in the future version of the paper.

References

Adsera, A., Pytlikova, M. (forthcoming). The Role of Language in Shaping International Migration. Forthcoming in the *Economic Journal*.

BARRIOS, S., Bertinelli, L., STROBL, E. (2006). Climatic Change and Rural–urban Migration: the Case of Sub-Saharan Africa. *Journal of Urban Economics* 60 (3), 357–371.

BORJAS, G.J. (1989). Economic Theory and International Migration. *Internetional Migration Review* 23 (3), 457–485.

CIPRA, Tomáš (2013). *Finanční ekonometrie.* ISBN 978-80-86929-93-4.

DOUGHERTHY, Christopher (2002). *Introduction to Econometrics.* ISBN 19 877 643 08.

FENG, S., OPPENHEIMER, M. (2012). Applying Statistical Models to the Climate–Migration Relationship. *Proceedings of the National Academy of Sciences* 109 (43), E2915.

HARRIS, John R., and Michael P. TODARO (1970). "Migration, Unemployment and Development: A Two Sector Analysis." *American Economic Review* 60 (5): 126–142.

HUGO, G. (1996). Environmental Concerns and International Migration. *International Migration Review*, Special Issue: Ethics, Migration, and Global Stewardship 30 (1), 105–131.

KAREMERA, D., V. J. OGULEDO and B. DAVIS (1997). A Gravity Model Analysis of International Migration to North America. *Applied Economics.* ISSN 1466-4283.

MARCHIORI, L., MAYSTADT, J.F., SCHUMACHER, I. (2012). The Impact of Weather Anomalies on Migration in Sub-Saharan Africa. *Journal of Environmental Economics and Management* 63 (3), 355–374.

MASSEY, Douglas S., Joaquin ARANGO, Graeme HUGO, Ali KOUACI, Adela PELLEGRINO, and Edward J. TAYLOR (1993). Theories of International Migration: A Review and Appraisal. *Population and Development Review* 19 (3): 431–466.

MAYDA, Anna Maria (2005). International Migration: A Panel Data Analysis of Economic and Non-Economic Determinants. *IZA Discussion Paper*.

MEYERS, N. (2002). Environmental Refugees: A Growing Phenomenon of the 21st Century. Philosophical Transactions of the Royal Society of London, Series B: *Biological Sciences* 357 (1420), 609–613.

MORTREUX, C., BARNETT, J. (2009). Climate Change, Migration and Adaptation in Funafuti, Tuvalu. *Global Environmental Change.* 19 (1), 105–112.

NAUDÉ, W. (2010). The Determinants of Migration from Sub-Saharan African Countries. *Journal of African Economies* 19 (3), 330–356.

PIGUET, E., Pécoud, A., De GAUCHTENEIRE, P. (2011). Migration and Climate change: An Overview. *Refugee Survey Quarterly* 30 (3), 1–23.

SJASTAAD, Larry A. (1962). The Costs and Returns of Human Migration. *Journal of Political Economy* 70 (5): 80-93.

STARK, Oded and Shlomo YITZHAKI (1985). Labour Migration as a Response to Relative Deprivation. Harvard University, *Center for Population Studies.*