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A critical review of human migration models

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ABSTRACT

Migration has always been a fundamental component of human history. During last decades several researchers have derived models for predicting mass migrations. This paper critically reviews the theories and models - qualitative structural and mathematical modelling of migration. It analyses the institutional causes of migration at the origin and the impacts of migration on destination. Migration as a consequence of climate change is also considered and modelled. Comparisons of different modelling processes provide a better understanding of migration modelling itself and the subsequent synthesis of models and variables show the differences and complementarities. The critical analysis conducted will greatly facilitate development of new more comprehensive models for migration in the future.

Keywords: Human migration, migration theories, conceptual modelling, climate change, mathematical modelling.

1. INTRODUCTION

Migration of people has always been a fundamental component of human history. The process of migration is an important, multi-dimensional and complex issue of population movement (Colin, 1988). Historical movement of persons show that migration may be temporary or permanent movement of people from one location to another; with the intention of moving to a new land, place or country. The movement however is typically from one country to another, but internal or within country migration is nevertheless very common. According to International Organization for Migration (IOM, 2012), there are now about 192 million people living outside their place of birth, which is about 3% of the world's population. The current annual growth rate of migration is about 2.9%. The origins of migrants worldwide are the most populated countries, such as India, China, Mexico, Brazil, and North-African countries. Migration tends to be from the group of the poorest countries in the world, with low GDP per capita ratio. The usual destinations for migrants are in general USA, Canada, Western European countries, and Australia, i.e. the countries with high GDP per capita ratios. Migration may involve individuals, family units or in large groups. Sjaastad (1962) believed that migration cannot be viewed in isolation; in that human decision making is usually both multi causal and shaped by individual agent(Smith et al., 2010). Broadly, the migration decision entails weighing the costs versus the benefits of migration.

Mostly there are three flows of migration: rural, urban and international. Rural-urban migration occurs, when the expected real income differential is positive (Hagen zanker, 2011). This kind of migration leads tourbanization increasing and can be the cause of lots of difficulties in cities such as; air pollution, fewer employment opportunities, traffic problems, poor education and health provision, poverty, etc. For example the African countries face major challenges related to their urban demographic structure and dynamics due to migration (Codjoe, 2012). Large number have migrated during last century and has drawn attention of various specialists and scientists e.g.; Hispanic immigration into the U.S.; the persistence of guest worker (Turks in Germany); more recent migration of the people of the Islamic faith into France, U.K., and Netherlands (Kardulias and Hall, 2007).

Migration models address several broad questions. Who migrates?, why they migrate?, where do the migrants come from and where do they go?, when do they migrate?, and the consequences of migration to the origin and destination locations?(Greenwood, 2005). Sandefur and Scott (1981) believed that there is an inverse relationship between age and migration. It is noted that younger people migrate more, because young people have a longer life expectancy. Nakosteen and Zimmer's reduced-form decision equation (1980) supports the fact that the probability of migration decreases with age; both for self-employed persons, and for women relative to men. Moreover they noted that women migrate not only because of economic motives, but also for marriage purposes, social constraints, as well as their rights and protection against domestic violence.

Sandell (1977) and Mincer (1978) on the other hand view migration as a family decision. Bigsten (1988) also considers migration in terms of a household decision. The family as a whole migrates if their net gain is positive. A family considers movements to the urban or rural sector depending on the marginal benefits based on the combined wages. The tendency for annual interstate migration propensities rise with education. It should be noted that migration declines sharply with increased distance, propensities to move over longer distances are considerably lower than for shorter distances. The migration of relatives and friends also determines who migrants (Greenwood, 1971a). It is well-known that the existence of employment opportunities, higher income levels and opportunities for education are some of the motivating factors.

It is now widely accepted that climate change is not simply manifested in changes in long-term average conditions. This may include changes in extremes or variability, and will be experienced via changes in the frequency and severity of events such as droughts and floods (Houghton et al., 2001). The mechanisms of displacement due to impacts of climate change can also be: rising sea-level, higher surface temperatures, disruption of hydrological cycles, and increasing severity of storms (Newland, 2011). It has been predicted that climate related vulnerable regions globally will lead to the large-scale movement of people, both nationally and internationally. The estimates are around 200 million to 1 billion climate change migrants by 2050 (Myers, 2002; Stern, 2007).

According to the World Bank (Dasgupta, 2007), if the sea level rises by one meter by the end of this century, 37 million people in the East Asian region will be affected. There have been some attempts to prevent migration associated with climate change through assisting people in ability to adapt with possible circumstances. These efforts include flood protection, land reclamation, engineering for more productive land use and the development of crop varieties more resistant to flooding, drought, higher temperatures, and increased salinity. These are climatic events that have been associated with some past migration events. Indeed the possible responses will be influenced by the prevailing social, political and economic conditions and this has been noted (Smit and Pilifosova, 2001). Researchers regularly attempt to account for both human socio-economic processes and biophysical processes when assessing vulnerability to climate change (i.e.Fraser et al., 2003; Ikeme, 2003; Leichenko and O'Brien, 2002; Smit and Skinner, 2002; McCarthy et al., 2001; Yohe, 2000; Bryant et al., 2000).

All migration models begin with the basic assumption that migration is a voluntary human action. In sum there are four main conclusions: (1) the more distant the move, the higher is the probability of a repeat move, presumably because information is less reliable at a distance; (2) when unemployment motivates the initial move, return moves are more likely, presumably because financial pressures tend to impair the effectiveness of job search; (3) household heads who are very young tend to return soon after their initial move, presumably because they are less experienced in making such important decisions and perhaps less informed about opportunities elsewhere; (4) The highly educated are likely to move on quickly, presumably because their opportunities are more national in scope and they process information efficiently (DaVanzo, 1983).

A few of the numerous worldwide databases that maintain records regarding international migrants and migrations are; United Nations Global Migration Database (UNGMD), OECD International Migration Database, Global Migrant Origin Database (Version 4), Migration Policy Institute (MPI) Migration Database, International Labour Organization (ILO) Migration Database (Hristoski and Sotiroski, 2012; Stair and Reynolds, 2010).

The goal of this paper is to critically review the theories, qualitative structural modelling and mathematical modelling of migration. First, paper reviews macro-level, micro level and meso-level theories of migration. This part also will categorize different theories into these three types. The second part will consider different qualitative structural modelling or conceptual representation of migration; immigration and acculturation, migration by E-R diagram, model of private proactive adaptation to climate change (MPPACC), migration in response to climate change, exploring the link between climate change and migration, and a conceptual framework for the "Drivers of Migration". Finally the paper will focus on a variety of mathematical modelling of migration; migration modelling based on adaptation to climate change, model of agent migration adaptation to rainfall change, economic models, modelling migration and regional labour markets: an application of the new economic geography model RHOMOLO, migration modelling by markov chain method, statistical models: time series and multiple regression analysis, the human capital model, models of return migration.

2. MIGRATION THEORIES

Migration theories can be classified according to the level they focus on. Micro-level theories focus on individual migration decisions, whereas Macro-level theories look at aggregate migration trends and explain these trends with macro-level explanations. The Meso-level is in between the Micro and Macro level, e.g. on the household or community level and can explain both causes and perpetuation of migration (Zanker, 2011).

2.1. Macro-Level Theories of Migration

The macro approach studies the patterns of migration of the whole population or certain social groups (for example, seniors, population in working-age period, etc.) characteristics of the origin and destination regions (such as climate, income, unemployment, etc.) are used as input variables for macro models of migration (Aleshkovski and Iontsev, 2014). The main goals of application of migration modelling at macro level are (Sandefur and Scott, 1981):

- Migration processes analysis, seeking for the key determinations of migration (i.e. influence of interregional differences in wages and unemployment rates on the intention of migration flows);
- Migration indicators forecast (i.e. forecast of the scale of migration flows from one region into another);
- Simulation of migration process development using the observed interconnections (i.e. analysis of possible changes in emigration under different scenarios of economic growth in the emigration countries).

The Neoclassical macro migration theories explain migration as part of economic development. Internal migration occurs as a result of geographical differences in the supply and demand of labour, mostly between labour-rich versus capital-rich countries. (Lewis, 1954; Ranis and Fei, 1961).In the extended neoclassical models, migration is determined by expected rather than actual earnings and the key variable is earnings weighted by the probability of employment (Bauer and Zimmerman, 1999; Massey et al., 1993).

Todaro (1969) augmented this theory to account for the significant urban unemployment that was found in many less developed countries. This theory assumes that an equilibrium will take place, which we do not find in the real world and some of the other empirical predictions e.g. wage equalization, have also not been found. (Harris and Todaro, 1970)

The World Systems theory (Wallerstein, 1974), which takes a historical structural approach, stresses the role of disruptions and dislocations in peripheral parts of the world, as a result of colonialism and the capitalist expansion of neoclassical governments and multinationals. The capitalist expansion has had profound consequences for migration issues, as not only the capitalist mode of production, but also the culture and stronger transportation, communication and military links penetrate peripheries. The world system theory of migration links the determinants of migration to structural change in world markets and views migration as a function of globalization, the increased interdependence of economies and the emergence of new forms of production (Massey et al, 1993; Silver, 2003). Globalisation not only affects the demand for labour or facilitates migrant networks, but also leads to loss of border control. The political setting is thus an important structural factor in migration decisions. For example some of the countries that would be considered peripheral in the world systems theory (the Communist countries) chose to do so due to political reasons and political motives also influence migration flows (e.g. of refugees).

Another macro-level model explaining rural-urban migration in less developed countries is Mabogunje's (1970) migration as a system model, in which he explains migration as a dynamic spatial process. Other authors (e.g. Kritz and Zlotnik, 1992) have also emphasised the importance of viewing international migration as an interdependent dynamic system, with own but interlinked systems for sending and receiving countries and feedback and adjustment coming from the migration process itself. It can also be linked to the world systems theory, discussed above.

Zelinsky's hypothesis of mobility transition (1971) argues that migration is part of the economic and social changes inherent in the modernisation process. He argues that patterns and rates of migration can be closely linked to the stage of modernisation (e.g. industrialisation) and demographic factors (e.g. high birth rates).

The Dual Labour Market theory (Priore, 1979) explains there is a primary sector providing well-paid jobs and a secondary sector, for unskilled jobs, e.g. manufacturing. Employment in the secondary sector fluctuates according to the economic cycle, making it unstable and uncertain work, again unattractive to native workers. This theory, as with world system theory, links migration to structural changed in the economy, but explains migration dynamics with the demand side of the argument (Massey et al., 1993). Dual labour market theory also argues that migration is driven by conditions of labour demand rather than supply. Arango (2000) provided an intelligent explanation for the coexistence of chronic labour demand for foreign nationals alongside structural unemployment in receiving countries. Complimentary to the dual labour market theory is Hoffmann-Novotny's approach of explaining migrations as a theory of social systems (Hoffmann-Novotny, 1981).

2.2. Micro-Level Theories of Migration

The micro approach focuses on the migration behaviour of individuals (families, households) and intends to explain the decision-making process by potential migrants to remain in a current residence or migrate to another one. Micro models of migration usually are based on disaggregated data (i.e. the characteristics of an individual) delivered from census or sociologic surveys. The main goals of application of migration modelling at micro level are:

- Analysis of the decision-making process by potential migrant (" to move or to stay?") seeking for the key determinations of the decision identification of the most "dynamic" (apt to migration) social groups;
- Analysis of the individuals` selection process between alternatives ("where to move?"), seeking for crucial factors affecting the "choice" of destination if a movement is started.

Lee (1966) was the first to formulate migration in a push-pull framework on an individual level, looking at both the supply and demand side of migration. Positive and negative factors at the origin and destination push and pull migrants towards migration or non-migration. As push and pull factors are largely a minor-image of each other, the framework has been criticized for its inability to determine dominant factors (De Haas, 2008).

Wolpert's stress-threshold model (1965) describes a behavioural model of internal migration, similar to a cost-benefit analysis, but assuming individuals that intend to be rational ex-ante, but are not necessarily so ex-post. Individuals have a threshold level of utility they aspire to. Fischer et al. (1997) therefore propose a more advanced version of the model, where the no risk and asymmetric information assumptions are dropped.

The neoclassical macro-level elaboration can be transferred to the micro-level model of individual choice and has been termed the Human Capital theory of migration (Todaro, 1969). Introduced by Sjaadstad (1962), the human capital theory enriches the neoclassical framework by incorporating the socio-demographic characteristics of the individual as an important determinant of migration outcome at the micro-level (Bauer and Zimmerman, 1999).

Another behavioural model, the value-expectancy model (Crawford, 1973) is a cognitive model in which migrants make a conscious decision to migrate for some values based on more than economic considerations. Values are specific goals, e.g. wealth, autonomy, security and self-fulfilment. There are also other similar micro-based individual behavioural decision making models, e.g. work by de Jong and Fawcett (1981) or the adjustment-to-stress approach of Ritchey (1976). The behavioural approach also considers non-economic factors and societal influences.

The New Economics of Migration (NEM) theory elaborated that migration decisions are not made by isolated individual actors but typically by families or household. It offered a new level of analysis and different nature of migration determinants and it shifted the focus of migration research from individual to mutual interdependence (Stark, 1999).In this theory migration decisions are not based on individual profit-maximizing calculations but are rather a household response to both risk and to the failures of a variety of markets; labour market, credit market or insurance market (Massey et al, 1993).The New Economics of Labour Migration (NELM) is the only migration theory that explicitly links the migration decision to the impacts of migration, with remittances being this link(Taylor & Fletcher, 2001).According to the NELM a household maximises joint income, status and minimises risks. All three aspects contribute to the migration decision of the household. In real life it is likely that migration decisions are influenced by both absolute and relative income considerations (Stark, 1991).The NELM extends the migration decision to also include risk and insurance considerations, household decision making and links the migration causes to the consequences. Therefore it is a more realistic and useful theory, even though it is still quite abstract and stylised and has some strong assumptions, like rationality.

2.3. Meso-Level Theories of Migration

Despite the fact that macro- and micro-approaches to modelling have traditionally evolved independently from each other, actual migration flows are always the results of a combination of decisions made by individuals. The necessity to combine two approaches to migration modelling was emphasized in 1970s and a conceptual framework for so-called meso- approach has been proposed in 1980s-1990s by Cadwallader. Through its emphasis on households and family it highlights the importance and relevance of institutions and non-economic factors for migration decisions and hence brings in meso-level indicators. Dual labour market theory and world system theory offer a set of structural variables, derived primarily from national or international levels. It's worthwhile to mention that meso-level is particularly important as it serves as the theoretical and practical interplay between social structure and human agency.

Another meso-level theory of migration is cumulative and circular causation (Massey, 1990), which shows how migration becomes more and more common since it has started, by sustaining itself. Past migration alters the context in which current migration decisions are made by changing the socio-economic context and macro environment of migrant households that then affect the migration decisions of future migrants.

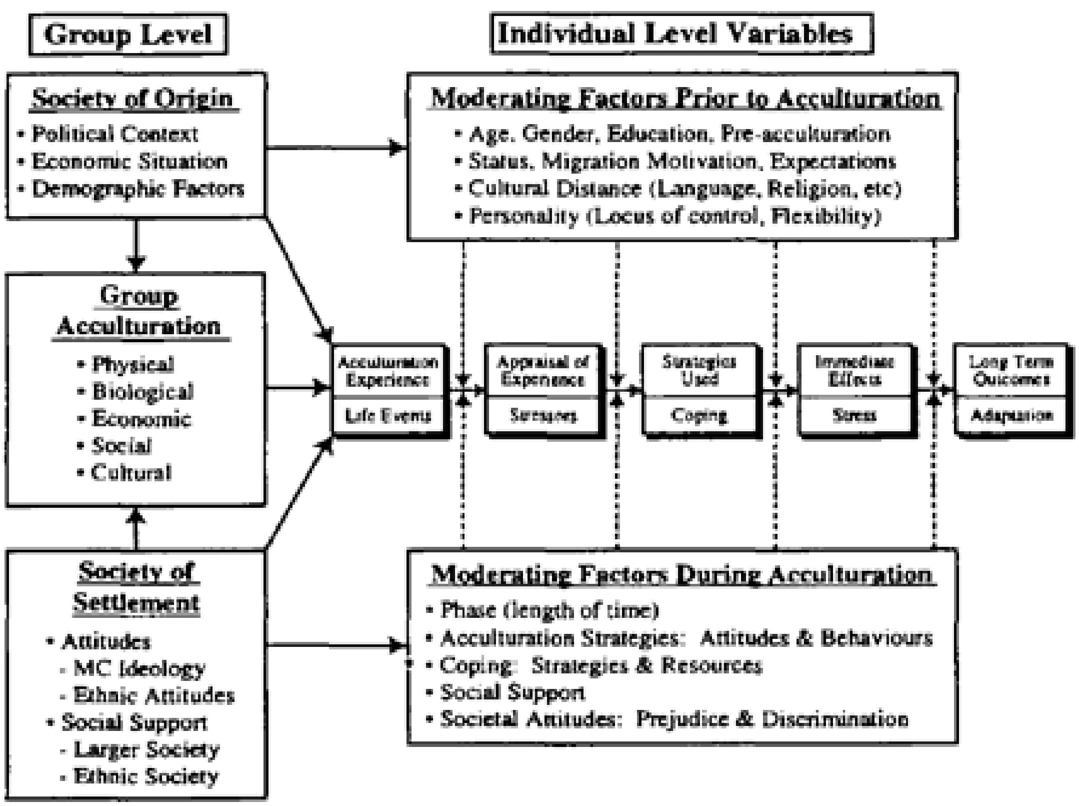

Figure 1 A Framework for Acculturation Research

3. QUALITATIVE STRUCTURAL MODELLING/ CONCEPTUAL REPRESENTATION OF MIGRATION

3.1. Immigration and Acculturation

Berry (1997) presented a conceptual framework for the process of acculturation and to illustrate the main factors that affect an individual`s adaptation. On the left of Figure 1 are group- or cultural-level phenomena, which are mainly situational variables; while to the right are individual- or psychological-level phenomena which are predominantly person variables. Along the top are features that exist prior to acculturation taking place, while along the bottom are those that arise during the process of acculturation. Through the middle of the framework are the main group and psychological acculturation phenomena; these flow from left to right beginning with the cultural groups in contact bringing about changes in many of their collective features (e.g. political, economic, social structures), then affecting the individual who is experiencing acculturation (resulting in a number of possible psychological experiences and changes, leading finally to a person's adaptation. The framework in Figure 1 combines both structural and process features: the central portion flowing from group acculturation through individual acculturation to adaptation is clearly a process taking place over time; factors in the upper and lower levels influencing this process provide the broad structure in which acculturation takes place.

3.2. Conceptual Modelling of Migration by E-R Diagram

It is important to know the direct reasons for a particular migration. These can be also grouped in several categories, including family related, job-related, housing-related and other reasons. Hristoski and Sotiroski (2012) proposed a conceptual data model for modern human migrations. Their model encompasses the static data about each migrant and also genealogical data (both successors and ancestors), as well as the relevant spatial and temporary data about migrants' movements. They compiled their model in the format of Entity-Relationship diagram (E-R diagram) which represents a relational database. The E-R model is expressed in terms of entities being identified in the given environment (area of interest), the relationships (associations) among those entities, and the attributes (properties) of both the entities and their relationships. An E-R model is normally expressed as an entity-relationship diagram (E-R diagram), which is a graphical representation of an E-R model (Hoffer, Prescott and McFadden, 2007). Figure 2 represents the E-R diagram. E-R diagrams use basic graphical symbols to show the organization and relationships between data being identified. In most cases, boxes indicate entities, ovals represent their attributes, and diamonds show the relationships among entities. Symbols of the diagram are defined as follows:

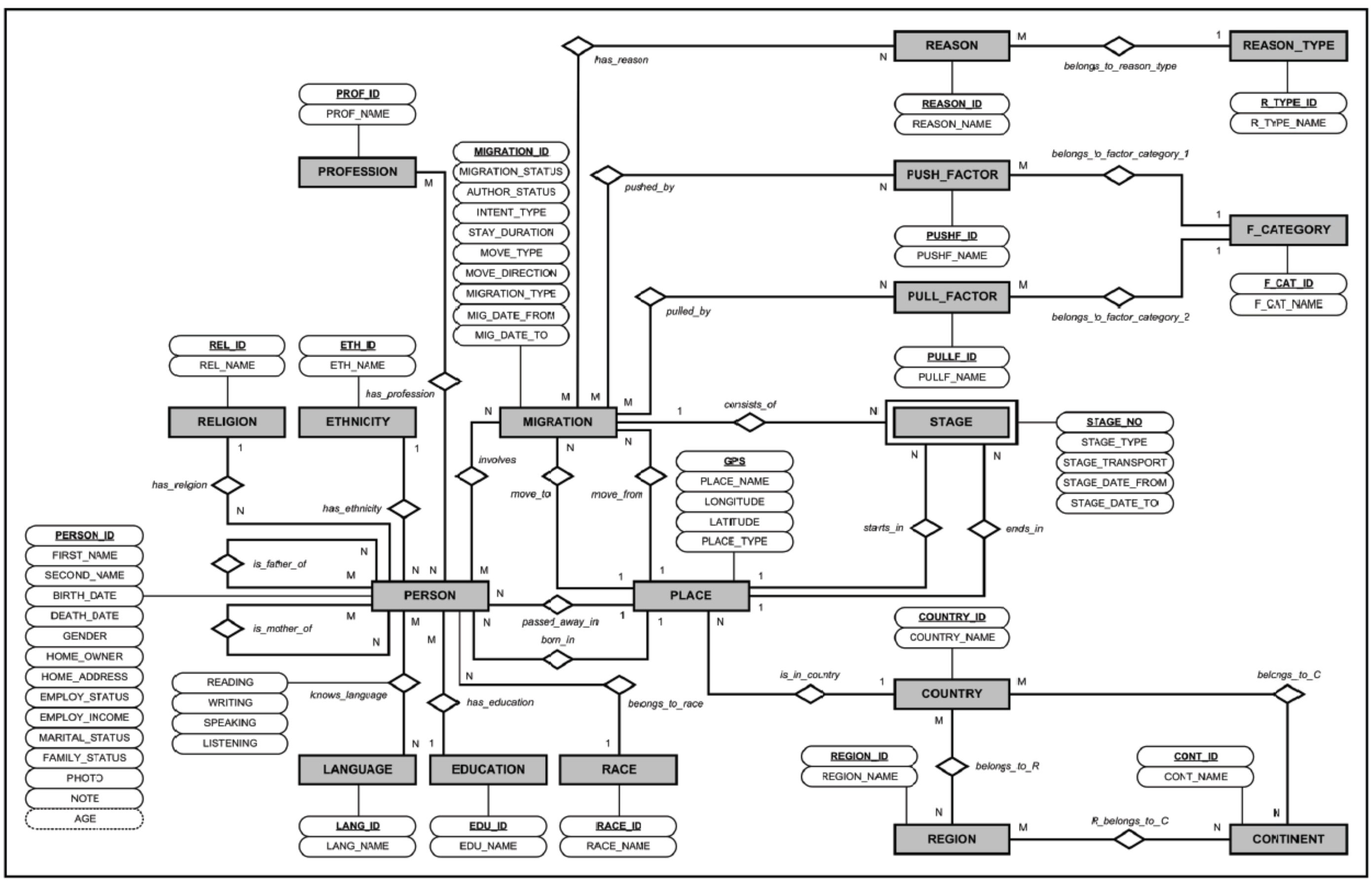

Figure 2 The E-R diagram of the modern human migration relational database

LANGUAGE (lang_id, lang_name), EDUCATION (edu_id, edu_name), RACE (race_id, race_name), ETHNICITY (eth_id, eth_name), RELIGION (rel_id, rel_name), PROFESSION (prof_id, prof_name), COUNTRY (country_id, country_name), REGION (region_id, region_name), CONTINENT (cont_id, cont_name), BELONGS_TO_R (country_id, region_id), BELONGS_TO_C (country_id, cont_id), R_BELONGS_TO_C (region_id, cont_id), REASON_TYPE (r_type_id, r_type_name), REASON (reason_id, reason_name, *r_type_id*), F_CATEGORY (f_cat_id, f_cat_name), PUSH_FACTOR (pushf_id, pushf_name, *f_cat_id*), PULL_FACTOR (pullf_id, pullf_name, *f_cat_id*), PLACE (gps, place_name, longitude, latitude, place_type, *country_id*), PERSON (person_id, first_name, second_name, birth_date, death_date, gender, home_owner, home_address, employ_status, employ_income, marital_status, family_status, photo, note, age, *edu_id*, *race_id*, *is_born_in_place*, *pass_away_in_place*, *eth_id*, *rel_id*), KNOWS_LANGUAGE (person_id, lang_id, reading, writing, speaking, listening), IS_FATHER_OF (person_id_1, person_id_2), IS_MOTHER_OF (person_id_1, person_id_2), HAS_PROFESSION (person_id, prof_id), MIGRATION (migration_id, migration_status, author_status, intent_type, stay_duration, move_type, move_direction, migration_type, mig_date_from, mig_date_to, *move_from_gps*, *move_to_gps*), STAGE (migration_id, stage_no, stage_type, stage_transport, stage_date_from, stage_date_to, *starts_in_gps*, *ends_in_gps*), INVOLVES (person_id, migration_id), HAS_REASON (migration_id, reason_id), PUSHED_BY (migration_id, pushf_id), PULLED_BY (migration_id, pullf_id).

3.3. Model of Private Proactive Adaptation to Climate Change (MPPACC)

Gorthmann and Patt (2005) developed a socio-cognitive Model of Private Proactive Adaptation to Climate Change (MPPACC). Based on the outcomes of the risk- and adaptation appraisal processes, a person responds to the threat. Two general types of responses can be differentiated: adaptation and 'maladaptation'. Adaptive responses are those that prevent damage, and are taken if the risk perception and the perceived adaptive capacity are high. 'Maladaptive' responses include avoidant reactions (e.g., denial of the threat, wishful thinking, fatalism) and 'wrong' adaptations that actually increase climate change damage although not intended to do so (e.g., rehabilitation programs that encourage development on flood plains and in exposed coastal zones) (Burton, 1996; Edris Alam, 2017). In their paper, they only focus on the avoidant maladaptive responses. They do not prevent monetary or physical damage in the case of a climate change impact, but only the negative emotional consequences of the perceived risk of those impacts (e.g., fear). A person would take an avoidant maladaptation if his or her risk perception is high but the perceived adaptive capacity is low. If the person chooses the adaptive responses, he or she first forms a decision or intention to take these actions.

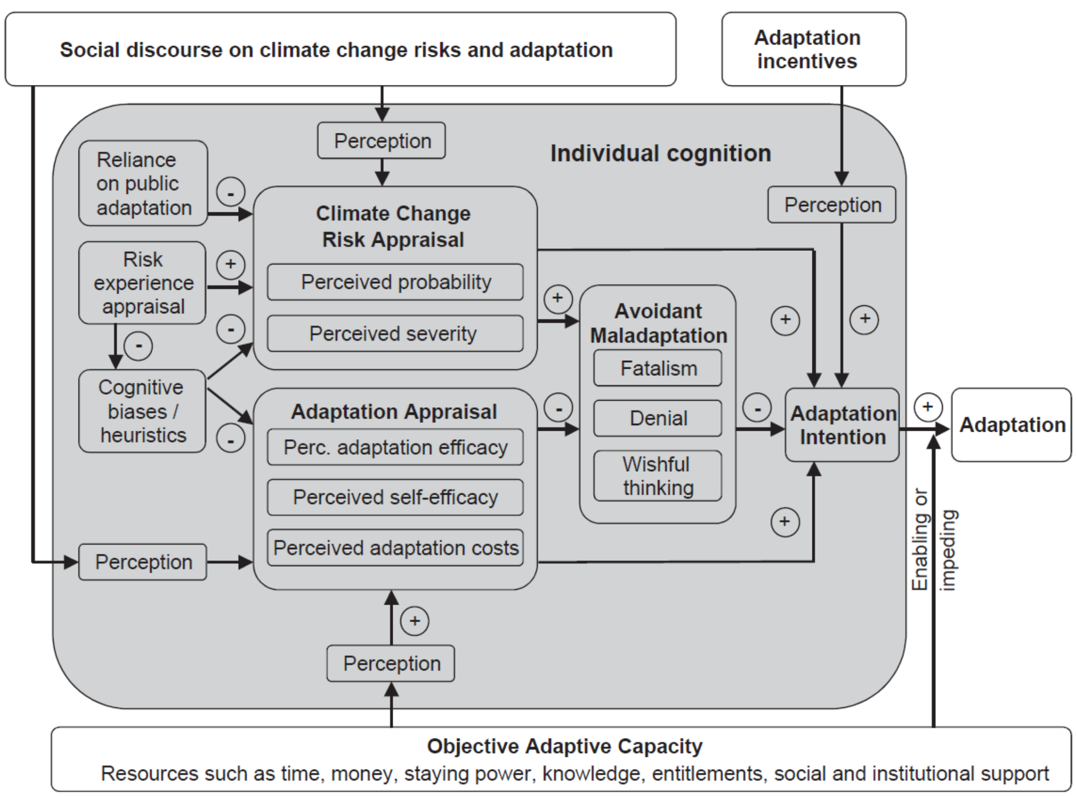

Figure 3 Process model of private proactive adaptation to climate change (MPPACC)

The important role of perceived adaptive capacity in their case studies recommends that in addition to the communication of risk people need to get information on possible, effective and not too costly adaptation options. If only the risks are communicated without communicating adaptation options, people will probably react by avoidant maladaptive responses like denial of the risk.

3.4. Model of Migration in response to Climate Change

Mcleman and Smit (2006) derived a model using the case of 1930s migration patterns in rural Eastern Oklahoma, which took place during a period of repeated crop failures due to drought and flooding. Figure 4 is a first step in conceptualizing how migration patterns may be influenced by climate change.

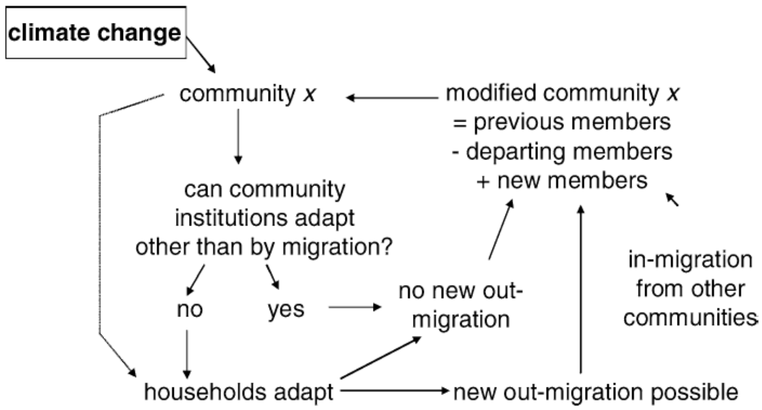

Figure 4 Model of migration in response to climate change

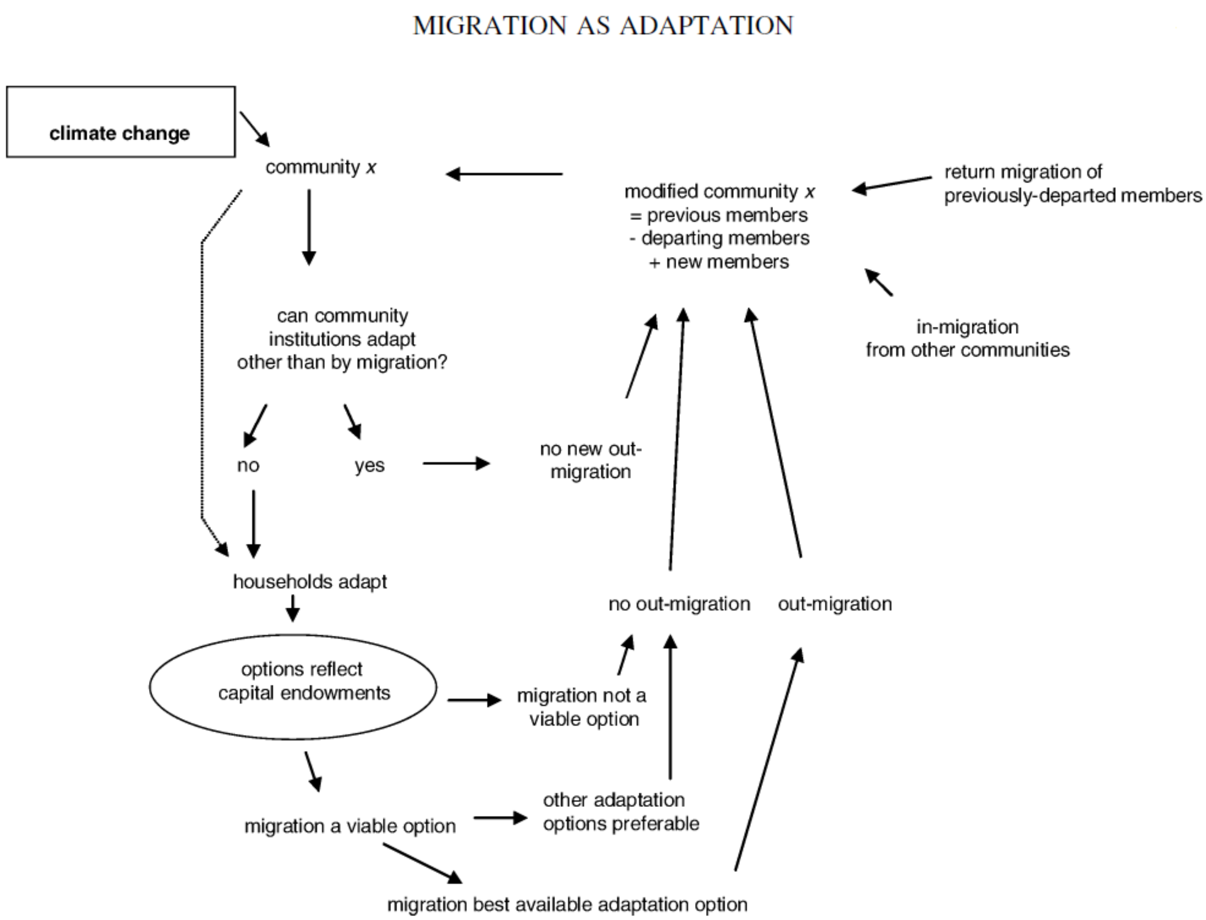

Figure 5 Model of migration in response to climate change, reflecting household capital

This model provides only a very basic framework for the climate-migration process. It focuses on how migration decisions are made as private adaptations at the household level, while still acknowledging that such decisions can occur at the public level. Figure 5 shows the climate change-migration model after being modified to incorporate capital endowments as a means of distinguishing different potential adaptive responses. The first model (Figure 4) has been modified to reflect migration theory in other ways. Migration is no longer portrayed simply as a binary phenomenon; rather, multiple possible outcomes exist, with capital endowments being influential. For the sake of simplicity, the migration outcomes are kept to a small number of possibilities. For the model to better reflect this possibility, a fourth path should to be added from the capital-endowments lens, showing that some households may have no option but to migrate (Figure 5).

The approach introduced in their paper considers the non-physical factors that influence migration decisions during periods of climate related stress. The model presented here is a tool that directs attention to the factors influencing vulnerability, and facilitates additional empirical research into human migration responses to climatic stimuli.

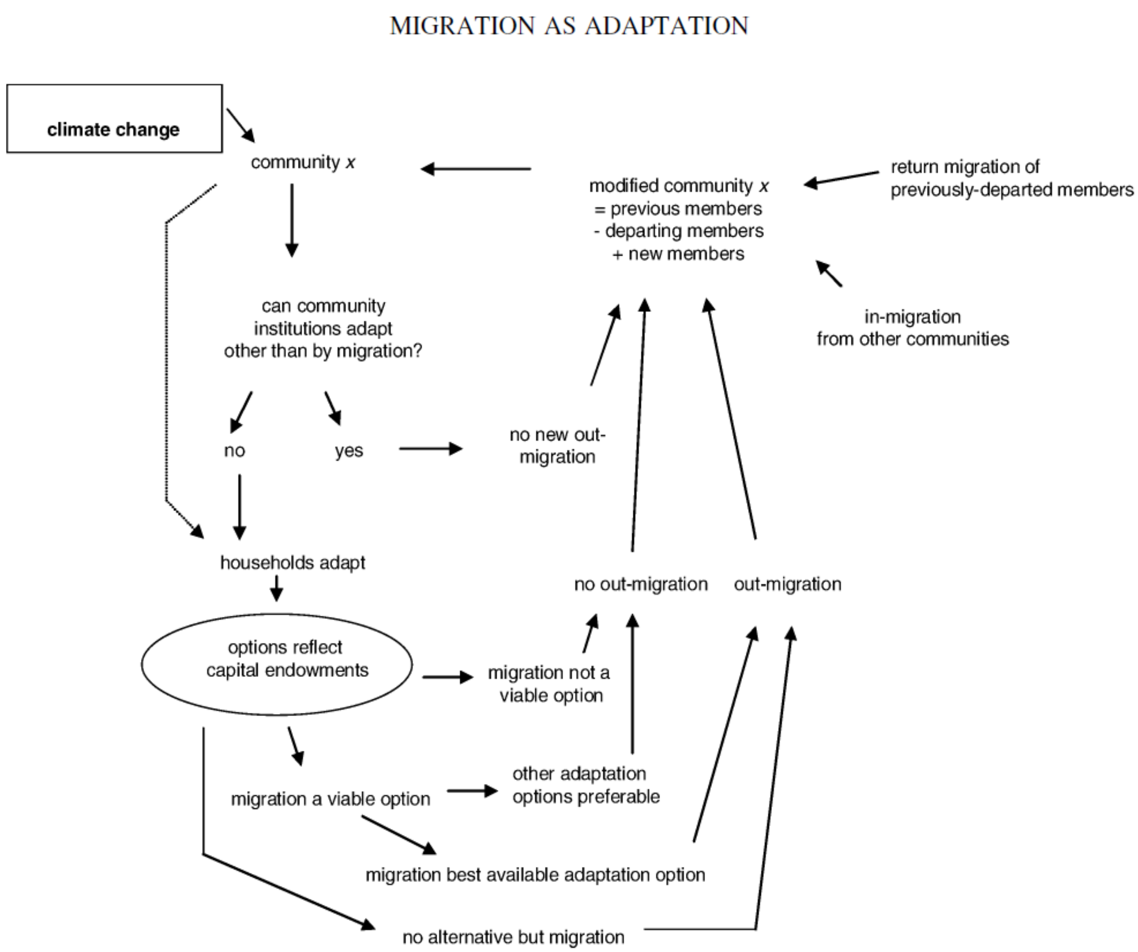

Figure 6 Model of migration in response to climate change, modified after case study

3.5. Exploring the link between climate change and migration

Nielson and Bättig (2008) presented two Conceptual model of the influence of climate change on migration. The goal of their paper has been to investigate the influence of climate change on migration on an intermediate level and make the linkage between the two explicit. For this purpose, conceptual models have been presented for two mechanisms that are likely to be increased or intensified by climate change: floods and sea level rise.

In Figure 7, floods caused by rainfall have been chosen as an example. The first linkages on the left show the role of climate change in increasing the risk of floods. Further to the right, the direct and indirect effects are depicted that can finally lead to migration but also to different types of adaptation (column on the far right). The choice of adaptation options influences how vulnerable the population in question is towards the next flood event. The strength of the influences (arrows) varies strongly. In general, the strength decreases from left to right (intense precipitation events have a strong effect on floods while reduced income might only be one of many factors influencing a migration decision).

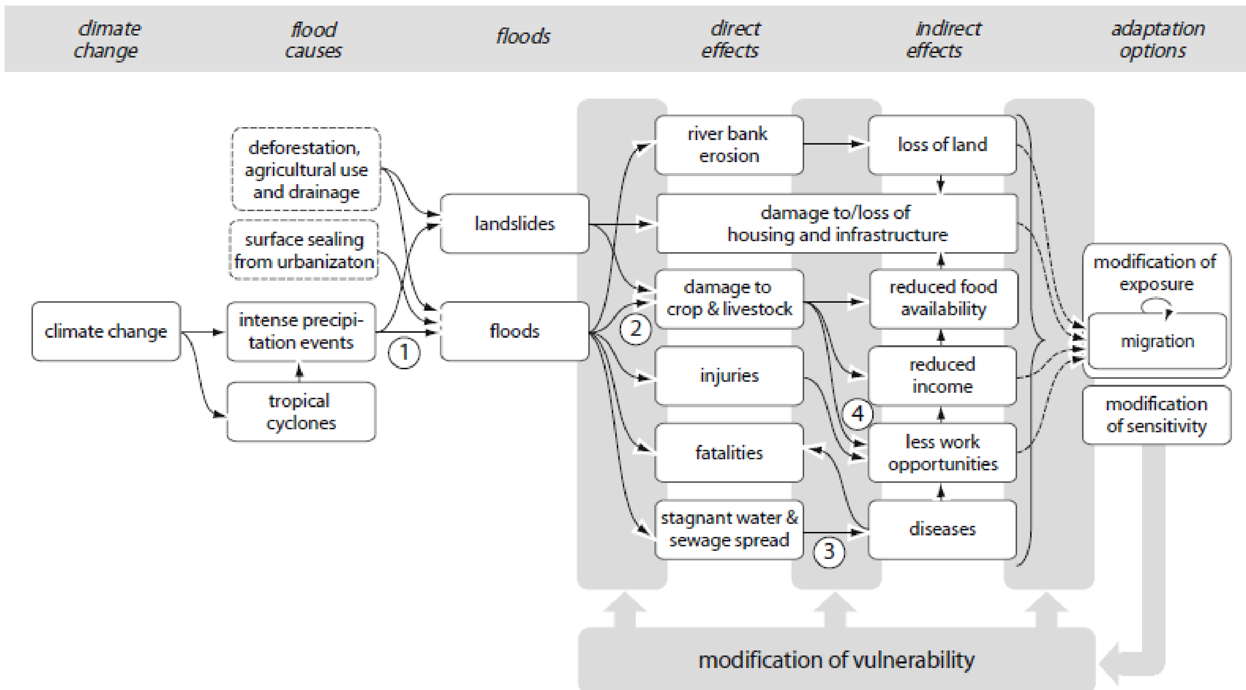

Figure 7 Conceptual model of the influence of climate change on migration through flooding

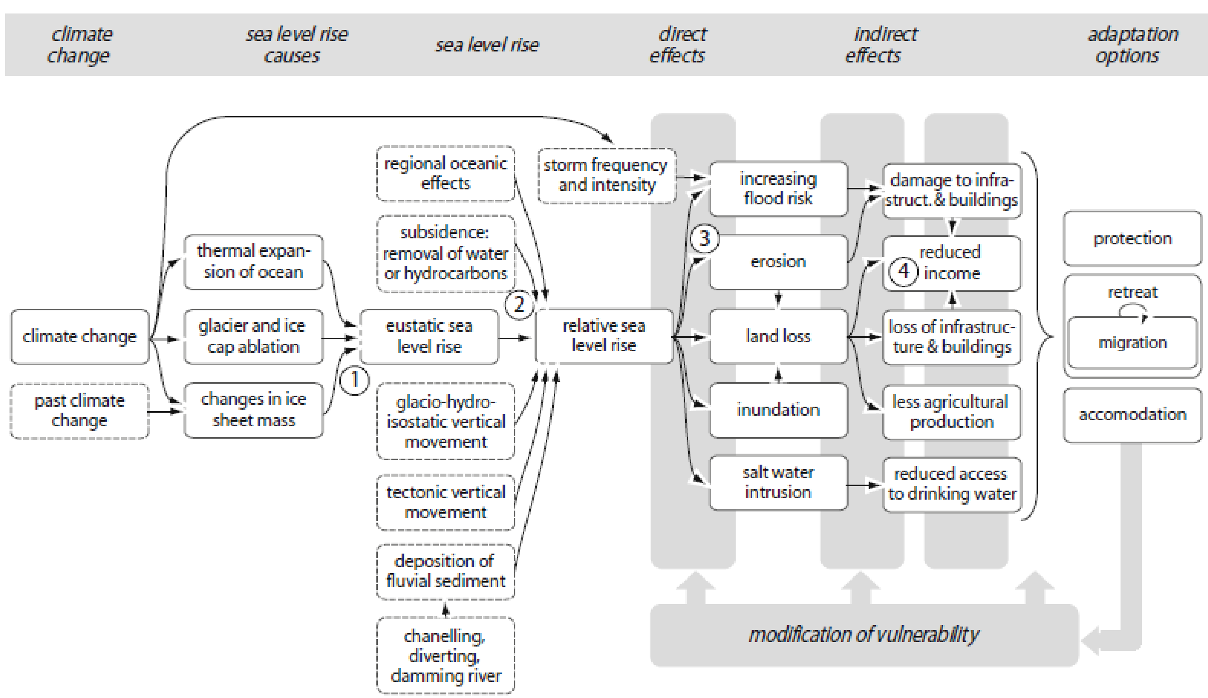

Figure 8 Conceptual model of the influence of climate change on migration through sea level rise

The way in which sea level rise is considered to affect migration is straightforward: "as land is lost because of sea level rise, there will be an increase of out-migration" (Leatherman, 2001). Adding intervening variables to this and depicting effects of sea level rise proves difficult due to the different time scales on which sea level rise acts. In contrast to floods, sea level rise is a process that has slow and constant direct effects (as inundation), but also acts in discrete time steps via storms and consequent flooding. This makes it more difficult to depict the effects in the conceptual model (Figure8). The linkages to the left show the role of climate change in raising the eustatic and relative sea level. To the right the direct and indirect effects are described that lead to migration and other types of adaptation options. These then affect the vulnerability of the society in question and with it whether an influence takes place or not (grey beams). A full account of all influences can be found in Perch-Nielsen (2004).

3.6. A Conceptual Framework for the "Drivers of Migration"

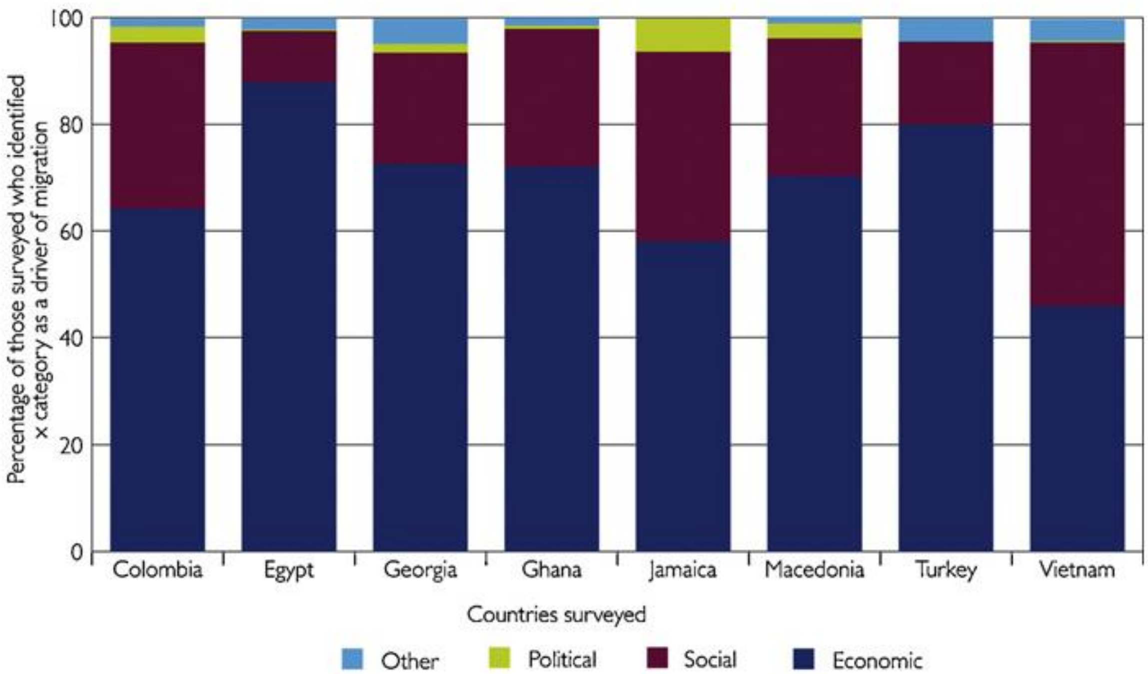

Figure 9 Self-reported migration motivations in national surveys

Black et al. (2011) presented a framework which identifies five families of drivers which affect migration decisions: economic, political, social, demographic and environmental drivers. At an empirical level, when people who have migrated are asked why they have done so, answers almost always cluster around economic and social factors, with environmental factors rarely mentioned, even when surveys specifically ask about such factors. Figure 9, for example, shows self-reported motivations for migrating by international migrants to the UK from a range of countries.

They seek to develop a framework which, rather than setting out theoretically what leads to migration, attempts instead to encompass the range of drivers that might affect the volume, direction and frequency of migratory movements, as well as the different levels of analysis at which migration might be considered. Figure10 summarizes this framework, which has four components:

(i) a distinction between different types of migration (the right hand side of Figure10), rather than types of migrant; (ii) the identification of five primary families of drivers of migration (the pentagon on the left hand side of Figure10), and the recognition that it is (actual or perceived) differences across space in these drivers which influence migration; (iii) the incorporation of agency in determining how drivers translate into outcomes, and specifically the representation of barriers and facilitators to movement; (iv) the incorporation of environmental change as a direct influence on migration, through changes to environmental drivers, and also as an indirect influence through changes to the other four drivers.

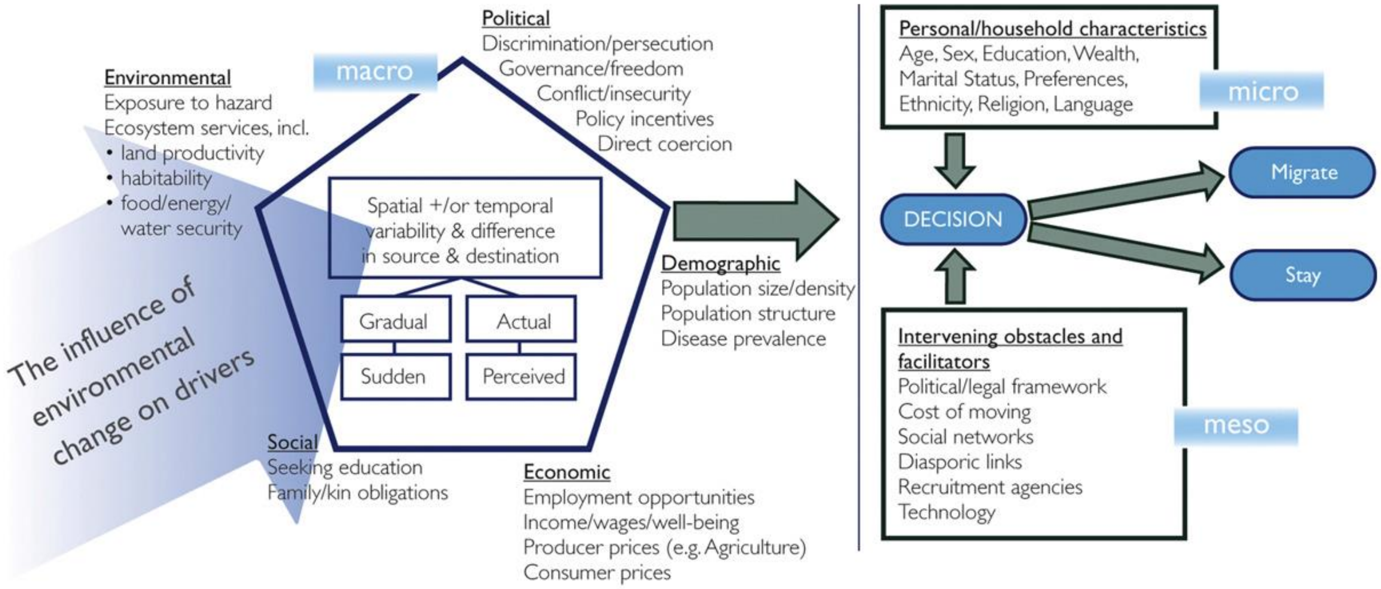

Figure 10 A conceptual framework for the 'drivers of migration'

4. MATHEMATICAL MODELLING OF MIGRATION

4.1. Gravity Model

The majority of the interaction models are attributed to gravity models of migration. These models consider spatial mobility of population in analogy with Issac Newton`s law of Gravity (1687) as interaction between two territorial units. English scientist George Stuart was the first to notice this peculiarity, having stated the so-called *gravity law of spatial interaction* in 1941:

$$F = kP_iP_jd_{ij}^{-2} \quad (1)$$

Where *F* is gravity or demographic force, *k* is a proportion coefficient, $P_i$is a population of the region of origin (*i*); $P_j$is population of region of destination (*j*), $d_{ij}$is a distance between interacting regions *i* and *j*.

More generally classical gravity model of migration can be presented as follows:

$$F = kP_iP_jd_{ij}^{-\alpha} \quad (2)$$

Where coefficient α ($\alpha > 0$) reflecting the friction associated with distance as *k* should be determined in the model.

Advantages of models of this type include, first of all, relative simplicity of developing and availability of statistical data for all level of analysis (inter-state, interregional migration, etc.). Major disadvantages of the gravity models comprise the migration flow symmetry assumption ($M_{ij} = M_{ji}$), which basically never happens in reality.

Generized gravity model can be represented as follows:

$$F = kP_i^{\beta}P_j^{\gamma}d_{ij}^{-\alpha} \quad (3)$$

Where *β, γ* and *α* are constant that reflect the relative weightings of the constituent variables.

If this model is expressed in double-log form, and then modified by some additional variables, then the results would be as follows (Greenwood, 2005):

$$ln\, M_{ij} = ln\beta_0 + \beta_1 lnD_{ij} + \beta_2 lnP_i + \beta_3 lnP_j + \beta_4 lnY_i + \beta_4 lnY_j + \sum_{n=1}^{m} \beta_{in} lnX_{in} + \sum_{n=1}^{m} \beta_{jn} lnX_{jn} + e_{ij} \quad (4)$$

where the *Y* terms refer to income. Other variables that are commonly included (as reflected in terms containing *X*) are unemployment rates, degree of urbanization, various climatological amenity variables, various measures of public expenditures and/or taxes, and many other factors. Modified gravity models are frequently estimated in double-logarithmic form, presumably because this functional form yields reasonably good fits and the coefficients obtained from it can be directly interpreted as elasticities of migration`s response to changes in the various independent variables of the estimated models. Modified gravity models hold an important place in the migration literature because their formulators tried to incorporate behavioral content into context of the gravity method.

4.2. Migration Modelling based on Adaptation to Climate Change

Livingstone et al. (2000) believed that characteristics of the natural environment determined the habitability of a region by humans and that the characteristics of people were shaped by attributes of the natural environment in the place in which they lived. In the climate change research community, researchers regularly attempt to account for both human socio-economic processes and biophysical processes when assessing vulnerability to climate change. Such approaches are captured in the following conceptual representation of vulnerability to climate change, modified from Smit et al. (2003), where:

$$V_{slit} = f\ (E_{slit}, AC_{slit}) \quad (5)$$

where, *V*=vulnerability, *E*=exposure, *AC*=adaptive capacity, *s*=a given system or community, l=a given location, *i*=a given climatic stimulus, *t*=a given period of time.

This conceptual model relates to the vulnerabilities of human systems (communities, sectors or regions), and recognizes that vulnerabilities are usually specific to particular types of climatic risk and particular locations and time periods. The elements of exposure and adaptive capacity are not static; as the subscripts imply, they vary according to the properties of biophysical and human social systems in a given geographic location, which change over time.

Robards and Alessa (2004) present this model in a slightly different fashion, to place further emphasis on the temporal nature of the relationships in the model, so that it becomes:

$$\frac{dV}{dt} = f(E_{(F+L+S)}, \frac{d\,AC}{dt}) \quad (6)$$

In this representation, vulnerability (*V*) is shown to change over time as a result of exposure (*E*) conditions and changes in adaptive capacity (*AC*) over time. The representation of exposure (*E*) in the model is expanded by showing that it varies according to the frequency (*F*), longevity (*L*) and spatial extent (*S*) of the climate related perturbation.

4.3. Model of Agent Migration Adaptation to Rainfall Change

Developed from the MPPACC (Modal for Private proactive adaptation to climate change) and the Theory of Planned Behaviour (Intended to aid prediction of behaviours over which a person does not have complete voluntary control), perceived behavioural control was conceptualised as the expected ease of actually performing the intended behaviour (Ajzen, 1991). Smith & Wood (2010) presented an agent-oriented model of an individual`s migration decision making as an adaptation strategy used in response to changes in climate; The conceptual model of Migration Adaptation to Rainfall Change (MARC) (Figure 11) is divided into four component levels: structural, institutional, individual and household.

In this model each individual considers their adaptation options on the basis of the three components borrowed from the Theory of Planned Behaviour: their attitude toward adaptation behaviours (BA), their subjective norm (SN) (or assessment of the expectations of others), and their perceived behavioural control (PBC) (or perceived adaptive capacity). An agent’s behavioural attitude is adjusted according to the combined impact of their networked peers (subjective norm) and their perception of whether or not they have the assets/experience necessary to undertake the migration (perceived behavioural control). Agents perform the intention calculation for each of the migration adaptation options available to them (Newland, 2011).

$$I = (BA \times SN) \times PBC \quad (7)$$

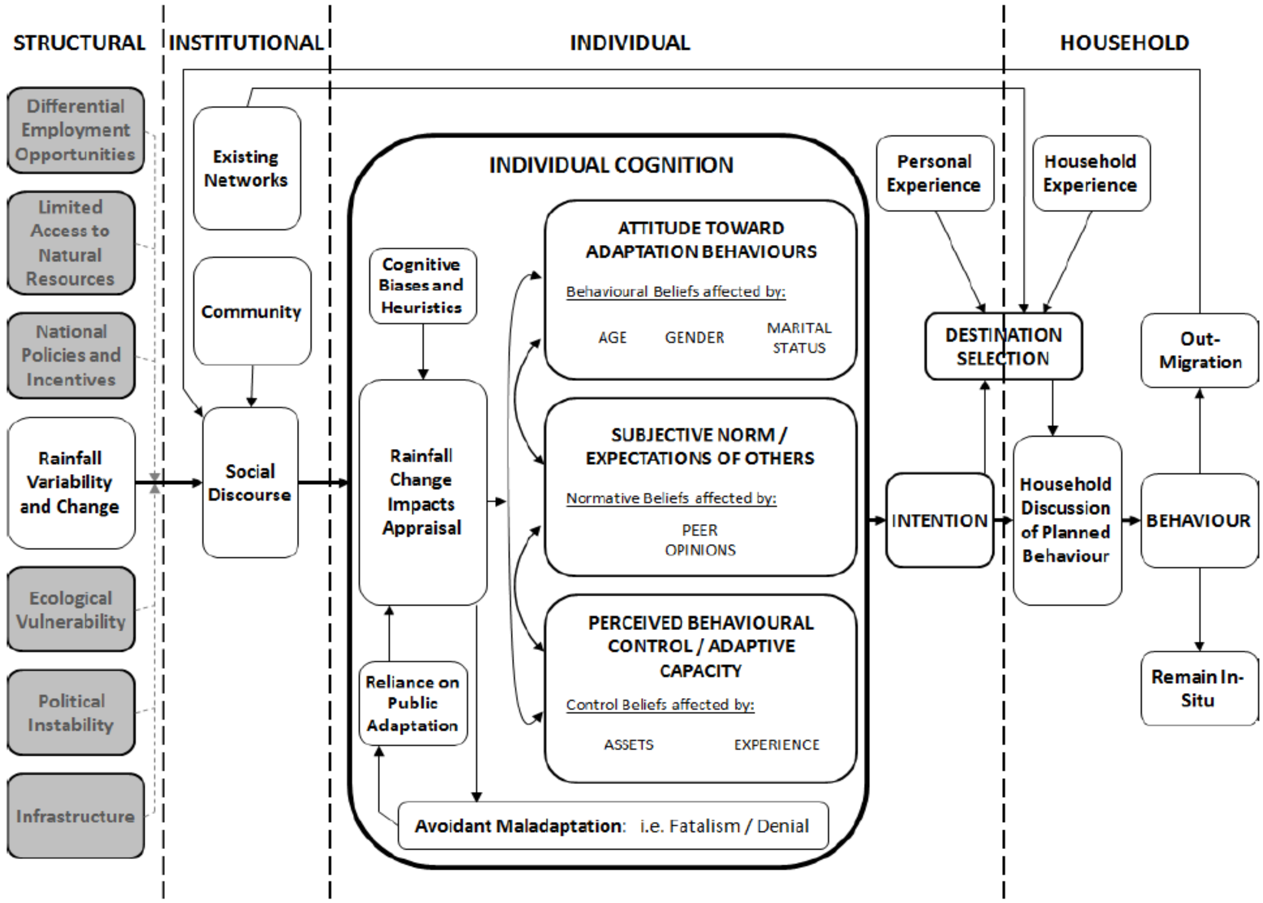

Figure 11 Model of Migration Adaptation to Rainfall Change (MARC)

PBC Value:

$$ra = r_1 + r_2 + r_3 \quad (8)$$

where Rainfall assets (*ra*) are calculated on the basis of the current year`s (r_1) and two previous years" (r_2, r_3) regional rainfall (measured in millimetres per month).

$$ar = la + (ra \times oc) \quad (9)$$

The asset rate (*ar*) that an agent uses in the calculation of their value incorporates both livestock assets (*la*) and rainfall assets (*ra*) and is dependent upon occupation (*oc*). (Calculated on the basis of a household`s stock of poultry, sheep, goats, donkeys and cattle, livestock assets (la) in the dataset range from 0.02 (1 chicken) to 45.6 (a herd of 228 cattle)).

$$er = \frac{de}{100} + \frac{ge}{1000} \quad (10)$$

Calculation of the experience rate (*er*), defined on the basis of an agent`s experience of migration to the destination in question (*de*) and their experience of migration in general (*ge*) is performed on the basis of above Equation.

If a random number (*rn*) between zero and one generated by the model is less than the resulting *BC* value, a binary score of 1 is allocated to *PBC*, migration is perceived by the agent to be within their means, and they continue to develop an intention value towards that option through Equation 7. Otherwise a value of 0 is assigned to and there will therefore be no intention to migrate.

BA Value:

The behavioural attitude (*BA*) component of the decision to migrate is, for each agent, selected from a matrix on the basis of the origin location (l) of the agent, the structural rainfall conditions (*rc*) that year and the current age (*a*) gender (*g*) and marital status (*s*) attributes of the agent. Who are migrants (*m*) from location l, under the prevalent rainfall conditions *rc*, divided by the population (*p*) of that location with the same defined attributes.

$$PV(A,G,S,L,RC) = \frac{m(a,g,s,l,rc)}{p(a,g,s,l)} \quad (11)$$

The adjusted probability value represents the behavioural attitude (*BA*) of the agent and is calculated on the basis of below Equation using the probability value for the relevant population of the agent`s origin location (*PV*) and the population of agents that have scored 1 for their value towards that option (*op*) in the current model cycle.

$$BA = \frac{PV(a,g,s,l,rc)}{op} \quad (12)$$

SN Value:

The subjective norm component of the decision to migrate is derived through an agent`s consideration of the opinions of their networked peers (*po*).

$$SN = f(po) \quad (13)$$

4.4. Economic models

Individuals make a rational cost-benefit calculation of the expected discounted returns of migration over future time periods, migrating only when the expected returns are positive. The formula below is one of the many variations that are used to model this approach.

$$ER(0) = \int_0^n [p_D(T)p_{ED}(t)Y_D(t)NR_D(t) - p_{EO}(t)Y_O(t)NR_O(t)]e^{-rt}dt - C(O) \quad (14)$$

The expected returns depend on the expected benefits and migration costs. Migration costs *C* consist of the monetary travel costs and non-monetary opportunity costs and psychological costs. The expected benefits consist of the discounted earnings (dependant on income at the destination Y_D and origin Y_O, respective employment probabilities p_{ED} and p_{EO} and the deportation probability p_D) and non-monetary returns (NR), e.g. a preference for the new location. The theory emphasizes that migration might lead to occupational upgrading (i.e. investment in human capital of the migrant). Age of the migrants obviously plays a significant factor. This model predicts that the young and educated migrate in the first phase (Sjaastad, 1962).

Economic models of migration take one of two possible broad theoretical perspectives: 1) disequilibrium and 2) equilibrium. For disequilibrium, the idea is that spatial differences in wages, earning, or income reflect opportunities for utility gains that can be realized through migration. In the equilibrium approach, migration is conditional on amenities. The equilibrium proponents believe that, at any point in time, it is highly likely that regional wages and prices have adjusted to their equilibrium values. (Greenwood, 2005)

The basic relationship of the migration function which has been used for econometric estimation is of the following form:

$$M_{ij} = f(D_{ij}, Y_i, Y_j, U_i, U_j, E_i, E_j, P_i, P_j, R_i, R_j, \dots, MS_{ij}) \quad (15)$$

M_{ij} = gross migration from origin region i to destination region j which is usually normalised in some way to allow for the effect of the population size of regions.

D_{ij} = distance between capital cities in regions i and j

Y_i, Y_j = a measure of income or wage rate in regions i and j.

$U_i U_j$ = unemployment rate in regions i and j.

E_i,E_j = educational achievement or literacy rate of population living in regions i and j.
P_i,P_j = population living in regions i and j.
R_i,R_j = urbanization rate of regions and j.
MS_{ij} = number of persons born in region i and living in region j which is usually referred to as "migrant stock" variable.

Multiple regression analysis with a double-log transformation is usually used for the estimation of above equation which is assumed to have a multiplicative form. Wadycki (1974a) selects P^*, U^* and W^* as the largest population, smallest unemployment and largest income from among all states other than the origin i and destination j states. The "improved" model consists of adding the variables P^*,U^*, and W^* defined in the above three ways to the "traditional" model:

$$A_{tj} = g_2(D_{ij}, P_j, U_j, W_j, P^*, U^*, W^*, random\ errors) \quad (16)$$

where,

A_{ij} = $M_{ij}/\Sigma jM_{ij}$ that is the proportion of total out-migrants from state i who moved to state j during a specilfic period of time.
D_{ij} = road mileage between capital cities of state i and j in kilometres
P_j = total population enumerated in state j
U_j = unemployment rate in state j (percent)
W_j = mediam money income of males living in state j.

The general economic equation of migration is mostly as follows:

$$\sum_{j=g}^{n} \frac{Y_{K'j} - C_{Kj}}{(1+r)^{n-g}} - \sum_{j=g}^{n} \frac{Y_{kj}}{(1+r)^{n-g}} = 0 \quad (17)$$

where *r* is the discount rate assumed to be the same in all future years. *J* refers to the year of migration and *j* is the number of year of migration. (j = g,... n). Human capital stock to level *i = K' (i = K, K',...).* $Y_{K'J}$ will enable him to earn an income stream in each year *j*. The costs incurred in year *j* are composed of the direct costs of the human capital investment C_{KJ}. If time is continuous rather than discrete, above equation is reformulated as:

$$\int_{j=g}^{n} (Y_{K'j} - C_{K'j})(t)e^{-rt}dt - \int_{j=g}^{n} Y_{K'j}(t)e^{-rt}dt = 0 \quad (18)$$

Gross migration flows from region *i* to region *j* are usually normalised to allow for the effect of the population size. The proposed normalisation equations are as follows (Paidousis, 2008):

M_{ij} / P_i (Schults, 1970) (19)

$M_{ij} / \sum_j M_{ij}$ (Sahota, 1968) (20)

M_{ij} / P_iP_j (Greenwood, 1971) (21)

$M_{ij} / (P_i+P_j)$ (Vanderkamps, 1971) (22)

where $M_{ij}$is the number of migrants from *i* to *j*, P_i and $P_j$are the population of the region *i* and *j* respectively. It should be pointed out although most of the researchers in this field prefer to use a normalised dependent variable there are some studies in which raw migration flows, the number of migrants from *i* to *j*, have been used instead (Levy and Wadycki, 1973). To our point of view the normalisations M_{ij}/P_i and M_{ij}/Σ_jM_{jj} seem to be more appropriate especially the second one. The economic variables in Graves's (1979) model are *income* and *unemployment* rate. Using annual data for the period 1951-1971, Walsh (1974) examines net migration from Ireland to Britain. Wages and unemployment rates are the main explanatory variables.

4.5. Modelling Migration and Regional Labour Markets: an Application of the New Economic Geography Model RHOMOLO

Brandsmaet et al.(2013) described the modelling approach of regional labour markets in the newly developed dynamic spatial general equilibrium model, Regional Holistic MOdeL (RHOMOLO), where the labour market equilibrium is determined by firms' labour demand, a wage-curve with unemployment and inter-regional labour migration. Their results confirm that wages and unemployment are by far the most important adjustment channels. In contrast, labour migration plays a secondary role in regional labour market adjustments in the EU. Regional Holistic MOdeL (RHOMOLO) is a dynamic spatial general equilibrium model, which recently have been developed by the European Commission. In order to assess spatially and temporally specific impacts of public policies, the model incorporates two important features: (i) the endogenous choice of location of workers and firms among all EU regions, regional linkages through trade flows, factor mobility, and knowledge spillovers; and (ii) inter-temporal investment decisions by firms to increase their productivity, and by workers to increase their skills, i.e., human capital. RHOMOLO is constructed in the framework of a spatial computable general equilibrium, incorporating key aspects of new economic geography models. In the model, the global economy consists of regional economies in the EU and one aggregate economy capturing the rest of the world. Each economy is disaggregated into six sectors.

Each region hosts two types of sectors: perfectly competitive and imperfectly competitive ones, implying that the output price, $p_{i,o,d}$ of firms is higher than marginal costs, $MC_{i,o,d}$:

$$p_{i,o,d} = \frac{1}{\Theta - 1} MC_{i,o,d} \quad (23)$$

Where $\frac{1}{\Theta-1}$ is the elasticity of total demand, and where origin region is *o*, destination region is *d*, and sector is *i*. Each region is endowed with two types of production factors: labour and capital. There are three types of economic agents in the model: households, governments, and firms. Each region hosts two types of sectors: perfectly competitive and imperfectly competitive ones. Consider *a* worker *k* from origin region o, maximising indirect utility, V_{kor}, across all possible destinations *r*. Destination *d* will be chosen if:

$$V_{kod} > V_{kor}, \forall r \in all\ regions, R \quad (24)$$

$$V_{kod} = Z_{od}\beta + \xi_{od} + e_{kod} \quad (25)$$

where the indirect utility V_{kor} of worker *k* migrating from origin region *o* to destination region *d,* is determined by the characteristics Z_{od}. Region *d* may vary with respect to origin region *o*, such as bilateral distance. The term $Z_{od}\beta$ represents the utility the worker receives from these characteristics, where β is a vector of marginal utilities. The error term ξ_{od}, represents unobserved location characteristics. $Z_{od}\beta$ and ξ_{od} assign the same utility level to all workers considering migration from *o* and to *d*. The idiosyncratic error term e_{kod}, which varies across both workers and regions, accounts for the fact that not all workers from the same region choose the same destination. They showed that probability of migrating from o to d can be interpreted as:

$$s_{od} = \Pr(M_{kod} = 1) = \frac{\exp\,(Z_{od}\beta + \xi_{od})}{\sum_{d=1}^{R} \exp\,(Z_{od}\beta + \xi_{od})} \quad (26)$$

and the share of those who stay in region *o* as:

$$s_{oo} = \Pr(M_{koo} = 1) = \frac{\exp\,(Z_{oo}\beta + \xi_{oo})}{\sum_{d=1}^{R} \exp\,(Z_{od}\beta + \xi_{od})} \quad (27)$$

Dividing Equation (2) by (3) and applying a logarithmic transformation yields a simple estimable migration equation:

$$\ln\left(\frac{s_{od}}{s_{oo}}\right) = (Z_{od} - Z_{oo})\beta + \sigma \ln\left(s_{od|c_d}\right) + (\xi_{od} - \xi_{oo}) \quad (28)$$

where c_d denoted any region in the country.

The empirical specification of the estimation equation then becomes:

$$\ln\left(\frac{s_{od}}{s_{oo}}\right) = \beta_1 \ln(income_0) + \beta_2 \ln(income_d) + \beta_3 \ln(distance_{0d}) + \beta_4 \mathrm{I}(international_{0d}) + \beta_5 \ln\left(s_{od|c_d}\right) + (\xi_{od} - \xi_{oo}) \qquad (29)$$

A dummy variable *I* (*international$_{od}$*) for international migration equals 1 in the case in which region *o* and *d* are located in different countries.

4.6. Migration Modelling by Markov Chain Method

Markov chain models have been developed and used by many researchers. In these models, various geographical locations are the states in Markov chains, and the transition probabilities are either empirically estimated or assumed to possess certain properties. (Henry et al., 1971)The main reason for using homogeneous Markov chain models was due to the fact that there were more detailed studies and results about them.

Pan and Nagurney (1994) have proposed a multistage network equilibrium model for human migration. The model formalizes a sequence of equilibrium conditions as equivalent variational inequality problems. Then they established the connection of such a model to the theory of Markov chains, focusing on the behaviour of the long-run population distribution. Under certain conditions, they showed that the stability of the one-step transition matrix guarantees the stability of the n-step transition matrix.

First they introduced network equilibrium conditions governing the migration model consisting of N locations as:

$$u_i(p) + c_{ij}(f) \begin{cases} = u_j(p), & if\ f_{ij} > 0 \\ > u_j\ (p), & if\ f_{ij} = 0 \end{cases} \qquad (30)$$

In the above, *f = (fij : (i,j) = (1,2), . . . , (N - 1, N))* is the vector of migration flows, where f_{ij} denotes the flow from location *i* to location *j*, *p = (pi, . . . ,p~)* is the vector of populations, where $p_i$denotes the population at location *i*, $u_i(p)$ is the utility function associated with locating at location *i*, and $c_{ij}(f)$ is the transaction, i.e., migration cost associated with moving from location *i* to location *j*.

Then they construct the Markov transition matrix at stage n based on VIn, the variational inequality formulation of the equilibrium conditions. This matrix can be written as follows:

$$P^{(n-1,n)} = \begin{bmatrix} \frac{f_{11}^n}{p_1^{n-1}} & \frac{f_{12}^n}{p_1^{n-1}} & \cdots & \frac{f_{1N}^n}{P_1^{n-1}} \\ \vdots & & \ddots & \vdots \\ \frac{f_{N1}^n}{p_N^{n-1}} & \frac{f_{N2}^n}{P_N^{n-1}} & \cdots & \frac{f_{NN}^n}{p_N^{n-1}} \end{bmatrix} = \left[p_{ij}^{(n-1,n)}\right], \qquad (31)$$

Finally, they provide a transition matrix as:

$$P^{(n-1,n)} = \begin{bmatrix} P_1^{(n-1,n)} & 0 & \cdots & 0 \\ \vdots & & \ddots & \vdots \\ 0 & & \cdots & P_k^{(n-1,n)} \end{bmatrix} \qquad (32)$$

where $(P_l^{(n-l,n)}, \ldots, P_k^{(n-l,n)})$ are irreducible stochastic matrices. The row numbers of the irreducible submatrix $(P_i^{(n-l,n)})$ correspond to a set of closed states *Si*. *Si* and *Pi* together form a sub-Markov chain.

4.7. Statistical models: Time series and multiple regression analysis

Milne (1981) employed annual migration data for each of the nine U.S. census divisions for the years 1960 to 1975. His data were developed by means of survival techniques. The Milne study thus incorporates 144 (9 x 16) observations on region-specific migration. He employed variable vectors for wage rates, unemployment rates, and population density. Since he has insufficient degrees of freedom to estimate his full model, he collapses each variable vector from nine elements to two, "own" and "other." For each region other is obtained via a weighting procedure that places heavier weights on nearer regions and that sums weighted values over all other regions. The degrees-of-freedom constraint, in combination with his desire to use three vectors, has forced Milne to place these restrictions on his model in order to reduce each of his three variable vectors from nine to two elements.

Moreover, without testing for their appropriateness (again due to lack of degrees of freedom) Milne imposes homogeneity restrictions on all sets of variable vectors.

Two types of new data have been particularly helpful in allowing empirical advances in migration research-(a) microdata and longitudinal data, and (b) time-series data, which tend to be aggregate. The availability of microdata has had several important consequences. (1) Studies using microdata have allowed the influence of personal characteristics on migration behaviour to be better measured and understood. Employment status is an important characteristic that has been usefully analysed in recent years. (2) Such data have also allowed an improved focus on the decision-making unit, be it the family, household, or individual. (3) Microdata have allowed better account to be taken of prior migration experience as an influence on current migration behavior. (4) Such data, especially those longitudinal in nature, have permitted some movement in the direction of studying important life-cycle influences on migration decisions. (5) Measurement of the returns to migration has been central to migration research, and the availability of microdata has permitted the development of far more meaningful implications than had hitherto been possible. The availability of time-series data on migration has also allowed important new developments. Time-series data allow the application of modern techniques to migration forecasting, but little work has yet been done in this area (Greenwood, 1985).

The key feature of the movement of migrants is that they do not jump from place to place completely randomly. Unlike Brownian particles in physics, in general the migration of people cannot be explained by a standard diffusion law, in which the flux is proportional to the gradient of number density of individuals. There are many extensions of the standard diffusion techniques (Okubo, 2001). Fedotov et al. (2008) derived a statically model for the growth of human settlements. They assumed that population growth is highly depend on food production and land fertility. The final equation of describing nonlinear movement was as follows:

$$\frac{\partial n}{\partial t} = \int p\big(q(x-z,t)\big)\lambda\big(\mathrm{q}(\mathrm{x}-\mathrm{z},\mathrm{t})\big)\mathrm{n}(\mathrm{x}-\mathrm{z},\mathrm{t})\rho(z)dz - p\big(q(x,t)\big)\lambda\big(\mathrm{q}(\mathrm{x},\mathrm{t})\big)\mathrm{n}(\mathrm{x},\mathrm{t}) + [1-p(q)]rn\left(1-\frac{n}{K(q)}\right). \qquad (33)$$

where *n* is density of migrants, (semi sedentary foragers/ sedentary farmers), *x* is location, *p* is population, *q* is local crop production per individual per year, z is jump of migrants, λ is frequency of jump *z* (jump rate), *r* is growth rate (0.01-0.03 yr^{-1}), *ρ(z)* is dispersal kernel and the carrying capacity *K* is, in principle, an increasing function of the local crop production *q*. In numerical simulations, *K* is assumed to be a constant.

They also derived an equation for crop production as follows:

$$q(x,t) = \alpha\left(\frac{n(x,t)}{n_0 + n(x,t)}\right)\left(1-e^{-\beta F(x,t)}\right) \qquad (34)$$

where F(x, t) is the density of soil nutrients, n_0 is the constant, is the production rate coefficient, and is the parameter that determines how the yield depends on the nutrients. This equation describes how the rate of food supply q increases due to the increase in the population density n and how the degradation of land (the decrease of soil nutrients F) leads to a decrease of food production. Finally their stochastic model gives an explanation for the formation of human settlements as a dynamical phenomenon. Moreover, their model describes the subsequent decay of the clusters due to land degradation and corresponding food crisis in the form of an extinction wave.

4.8. The Human Capital model

One implication of this model is that the individual will supply labour such that the marginal rate of substitution of consumption for leisure equals the wage rate, which in turn implies that the individual labour supply is a function of the wage rate. If we abstract from mobility costs and accept many other assumptions that underlie this simple yet powerful model, the individual is expected to offer his labour services in the market with the highest wage, which may require migration. The final format of "present value" of this model is as follows:

$$PV_{ij} = \sum_{t=1}^{n} \frac{1}{(1+r)^t}\left[\left(E_{jt}-C_{jt}\right)-\left(E_{it}-C_{it}\right)\right] \qquad (35)$$

where *E, C* and *r* represents earning, cost and internal rate of discount respectively. Earning of migrant is dependent on person`s age, education, marital status, family situation and numerous other personal characteristics (Walsh, 1974).

4.9. Models of Return Migration

Adda and Dustmann (2000) derived a model based on Germany inflow and outflow migrants in the period of 1984 to 2003. They assumed that each agent has in every period a choice of location between his country of origin and the host country.

$$V(A,G,Y,\lambda, S,\eta_S\eta_R) = \max\{V^{Stay}(A,G,Y,\lambda) + \eta_S, V^{Return}(A,G,Y,S) + \eta_S\} \qquad (36)$$

Let V $(A, G, Y, \lambda, S, \eta_S, \eta_R)$ be the lifetime value of an individual of age *A*, who has been in the host country for *G* years and with a stock of asset *S*. *Y* is the GDP in the home country, relative to the host country. λ is a shock to preferences, while in the host country. η_S and η_R are two taste shocks, assumed to be iid and which follow an extreme value distribution. Let $V^{Stay}(A, G, Y, \lambda)$ be the value of staying one additional period in the host country and $V^{Return}(A, G, Y, S)$ the value of going back to the home country permanently at the beginning of the period.

The agent compares at each period the value of staying for one additional period and the value of returning at the beginning of the period. The value of staying is defined as:

$$V^{Stay}(A,G,Y,\lambda) = u^{Stay}(G,\lambda,c^S) + \beta E_{Y,\acute{\lambda}|\,Y,\lambda,\eta_S,\eta_R}, V\left(A+1,G+1,\acute{Y},\acute{\lambda}\right) \qquad (37)$$

and the value of returning as:

$$V^{Return}(A,G,Y,S) = \max u^{Return}\,(A-G,c^R) + \beta E_{\acute{Y}|\,Y}V^{Return}\left(A+1,G,\acute{Y},\acute{S}\right) \qquad (38)$$

The utility derived in the host country u^{Stay}, depends on the time spent in this country, *G*, on the realization of the taste shock, λ and on the consumption in this country, c^S. The consumption in host is fixed at $c^R = 1-\rho$, as ρ is the percentage of income devoted to savings in host country. The taste shock follows a Markov process, and the agent has rational expectation over future realizations$\acute{\lambda}$. In the home country, the agent derives utility from consumption $c^R$and from the time spent in that country *A - G*. The agent migrates to the host country, either because he has a strong preference for the host country (*a* high λ), or because the host country offers a better technology to increase his savings *S*.

$$\begin{cases} u^{Stay}(G,\lambda,C^S) = \lambda C^{S\alpha}G^{\gamma} \\ u^{Return}(A-G,C^R) = C^{R\alpha}(A-G)^{\gamma} \end{cases} \qquad (39)$$

5. DISCUSSION

Common effects of migration are generally seen in the distortion of demographic structure at both the places of origin and destination (Raj, 1981). Both the origin and destination place are characterized by favourable, unfavourable and neutral factors. In fact, the origin and destination has positive, negative and neutral characteristics, which are directly or indirectly related to the process of immigration of a person. Positive or favourable characteristics of a place are called as pull factors and similarly negative or unfavourable or forces found operating at a place are called as push factors. All positive, negative and neutral factors operating at origin and destination place belong to geographical (physical/ environmental), demographic aspect, social, cultural, religious, economic and political groups (BRK, 2005).

More specifically, there are two broad issues that need to be brought in; the institutional cause of migration at the origin and the impacts of migration on destination. These issues had been noted in many articles. In this paper these are summarized in diagrams. As Figure 12 shows, causes of migration can be classified into seven factors; extreme climate events, education, marriage, social, economic, technology, and political issues. Importantly, each factor has also some sub-factors such as; Extreme climate events can include both drought and flood. In case of people looking for advancing their education, brain drain can occur especially in developing countries. In other cases divorced women can start a new life elsewhere. There are also social issues that can be cause of migration. Some of these are highlighted here; Crime, to be away from Capitalist, pollution, sanitation, gender equity and heavy taxation. Various economic factors are likely to affect migration decision making; Employment, wage, trade and cost of living. More demand of technology in sort of urbanization and modernization could also be reasons for migration. Looking at political issues, migration can be occurred due to ethnical conflicts, fear of persecution, war and religious constrains.

Migration has many effects on destination that in turn also influence the decision-making process of future migrants (Zanker, 2011). Figure 13 provides an overview of the impacts of migration on destination. As it shows, migration affects economic development; migrants mostly try to send remittances to their origin, they require the government to provide them with insurance and health services and in contrary more taxes would be paid to the government. Migration affects social issues like rate of population growth. This can also lead to heavy traffic as well as inadequate infrastructures. Environmental aspect is also one of the critical aspects of migration. Due to population growth, overexploitation of local environment and air pollution can be arising. Cultural effects can take place in many ways such as changing in ethnic composition of the society. Finally, Occupational opportunities are affected at the destination location and the highly impacted are those in low-skill jobs.

The level of analysis of migration shifts from micro-level to macro-level decision processes. Table1 presents a review on migration theories in different levels. The neoclassical theory of migration has both macro-level and micro-level elaborations. It focuses mainly on economic and labour market/employment issues. The world systems theory of migration considers capitalism, globalization and political issues. Zelinskey's hypothesis (1971) offers economic, social, modernization and demographic variables. Dual Labour Market theory concentrates on employment and economic parameters. According to lee's push and pull theory, all negative factors of the origin can be as push factors and clearly all positive factors of destination would be as pull factors of migration decision making.

Table 1 Review of Migration Theories

Migration Theories		
Theory	**Model**	**Parameters**
Macro-Level Theories of Migration	Neoclassical macro-level theories	Economic issues, labour marketing/ employment
	World Systems theory	Capitalism, globalization, political issues
	Zelinsky's hypothesis	Economic, social, modernization process, demographic factors
	Dual Labour Market theory	Employment, economic
Micro-Level Theories of Migration	Lee's Push and pull theory	All positive and negative factors at origin and destination
	Human Capital theory	socio-demographic characteristics
	Neoclassical micro-level theories	All like macro-level but in individual choice
	New Economics of Migration (NEM) theory	Family decision making
	The New Economics of Labour Migration (NELM)	Link migration causes to the consequences, minimises risks, economic, household decision making
Meso-LevelTheories of Migration	Dual labour market theory	theoretical and practical interplay between social structure and human agency
	World system theory	theoretical and practical interplay between social structure and human agency
	Cumulative and circular causation	Socio-economic context, environment

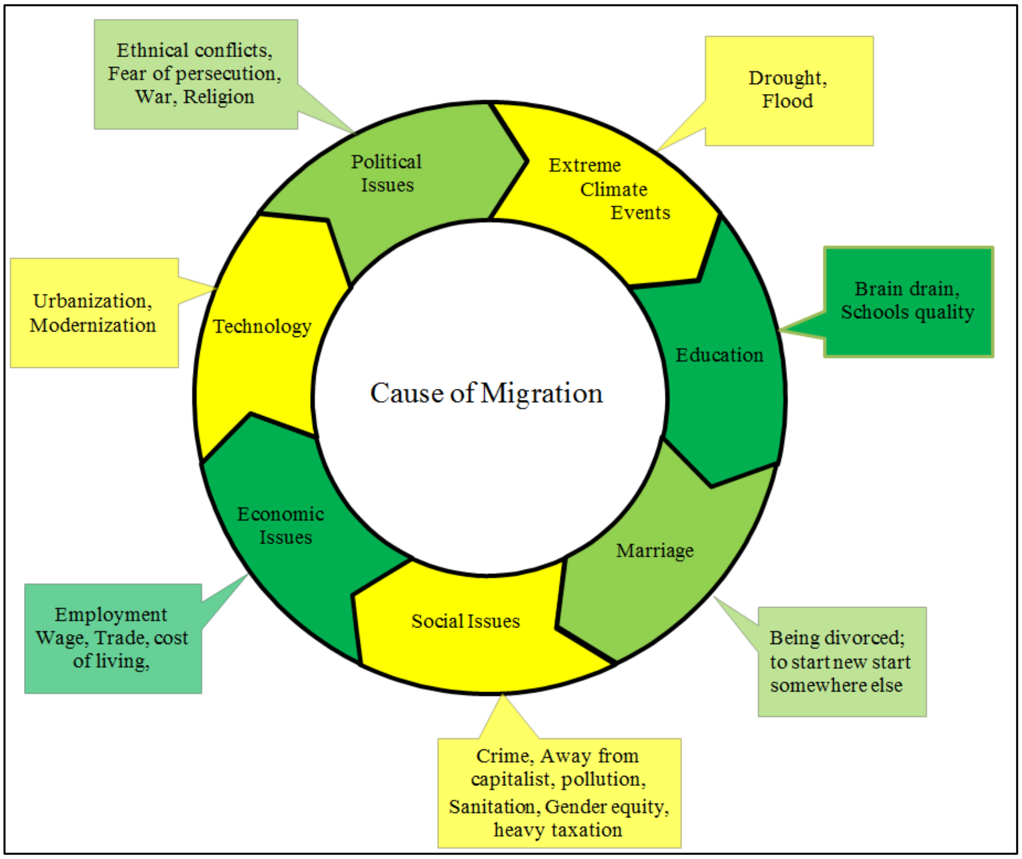

Figure12 Cause of migration

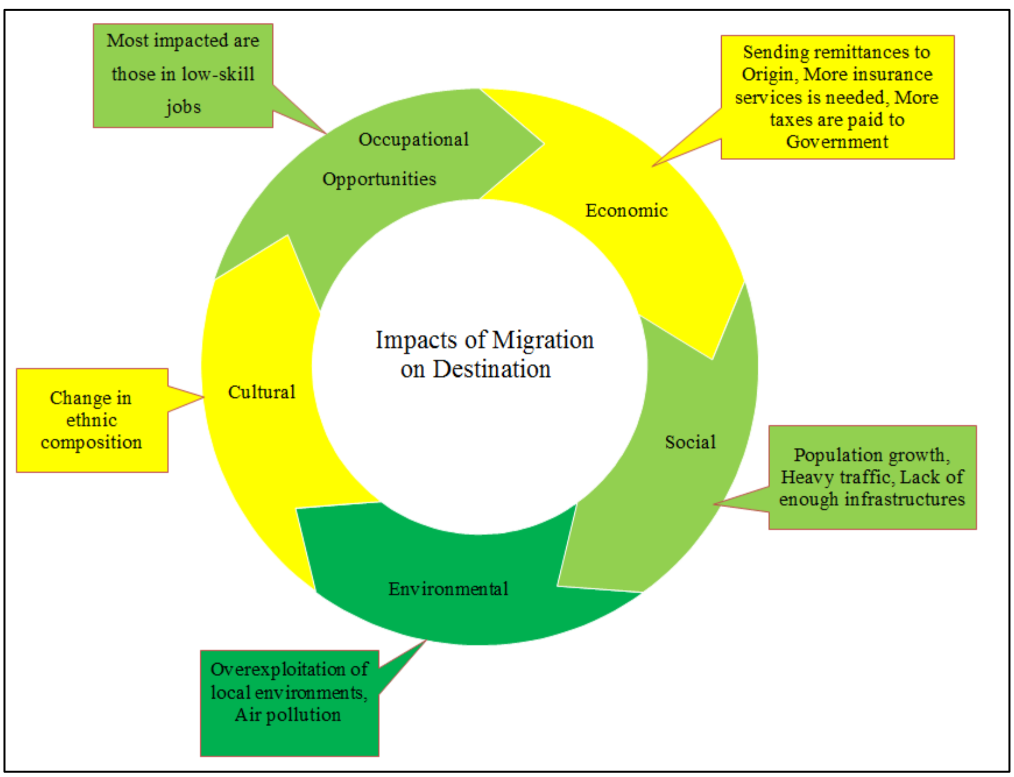

Figure13 Impacts of migration on destination

The human capital theory introduces socio-demographic characteristics of migration. The key argument of the new economics of migration (NEM) is that migration decisions are mostly made by families not by isolated individuals. The new economics of labour migration (NELM) primarily link migration causes to the consequences and minimizes risks. Generally it is depended on economy and household decision making. At meso-level, dual labour market and world system theory both focus on theoretical and practical interplay between social structure and human agency. A final meso-theory of migration is cumulative and circular causation theory which mostly involves socio-economic and environmental contexts.

Following to above discussions about migration theories, a variety of studies had been conducted to conceptualize the migration patterns in different regions. An overview of qualitative structural modelling/ conceptual representation of migration is proposed in Table 2. Immigration and acculturation encompasses cultural, psychological, political, economic, social and education variables. The Entity-Relation (E-R) diagram mostly focused on language, education, race, religion and profession factors.

Table 2 Review of Qualitative Structural Modelling/ Conceptual Representation of Migration

Qualitative Structural Modelling/ Conceptual Representation of Migration	
Model	**Parameters**
1. Immigration and Acculturation	Cultural, psychological, political, economic, social, education
2. Conceptual Modelling of Migration by E-R Diagram	Language, education, race, religion, profession
3. Model of Private Proactive Adaptation to Climate Change (MPPACC)	Social, climate change factors
4. Model of Migration in response to Climate Change	Climate change factors, non- physical factors (e.g. household decision making),
5. Exploring the link between climate change and migration	Effects of flood and sea level rise
6. A Conceptual Framework for the "Drivers of Migration"	Economic, political, social, demographic, environmental

As discussed previously, during last few decades many articles have investigated the effects of climate change on the migration process. MPPACC considered social and climate change factors while in advancing, model of migration in response to climate change. The model developed relationship between climate change factors and household decision making. In exploring the link between climate change and migration, the effects of two mechanisms, flood and sea level rise, which are likely to be increased or intensified by climate change were analysed. The conceptual framework for the "Drivers of Migration" identifies five families of drivers that affect migration decision making: (I) economic, (II) political, (III) social, (IV) demographic, and (V) environmental drivers.

Table 3 provides an overview of mathematical modelling of migration in terms of the variables and equations. The equation of modified gravity model is of a logarithm type and includes variables such as; population, distance, income, unemployment, urbanization, climatological variables and taxes. The second model is based on adaptation to climate change and has a differential equation format involving vulnerability, adaptive capacity, frequency, longevity, and climate factors. The third model is agent migration adaptation to rainfall change including a variety of variables such as; adaptation behaviours, subjective norm, perceived behavioural control; rainfall assets, livestock asset, occupation, experience and general information about migration, age, gender, marital status, rainfall condition, migration information and consideration. This model has various functions and rules defined. The fourth models are economic models that have an integral type of equation and emphasis on monetary, non- monetary, psychological costs, distance, income, unemployment, educational, population, urbanization, and human capital investment variables. The fifth models area logarithm type that deal with regional labour markets, wage, unemployment, and distance variables. The sixth models are Markov chain models which make link between perpetuation of migration and population flows and it has a matrix type. The seventh type are statistical time series but include integral/differential type of equations and highlight the role of wage, unemployment, population density, and crop production factors on migration. The next human capital model considers labour market, wage, mobility costs, age, education, marital status variables in modelling migration and involves economic type of equations. The ninth type of optimization models allow for return migration but also concentrate on age, asset and GDP parameters.

Table 3 Review of Mathematical Modelling of Migration

Mathematical Modelling of Migration		
Model	**Variables**	**Equations**
1. Gravity Model (modified)	Population, distance, income, unemployment, urbanization, climatological variables, taxes	$\ln M_{ij} = \ln\beta_0 + \beta_1 \ln D_{ij} + \beta_2 \ln P_i + \beta_3 \ln P_j + \beta_4 \ln Y_i + \beta_4 \ln Y_j + \sum_{n=1}^{m} \beta_{in} \ln X_{in} + \sum_{n=1}^{m} \beta_{jn} \ln X_{jn} + e_{ij}$
2. Migration modelling based on adaptation to climate change	Vulnerability, adaptive capacity, frequency, longevity, climate factors	$\frac{dV}{dt} = f(E_{(F+L+S)}, \frac{d\,AC}{dt})$
3. Model of Agent Migration Adaptation to Rainfall Change	Adaptation behaviours, subjective norm, perceived behavioural control; Rainfall assets, livestock asset, occupation, experience and general information about migration, age, gender, marital status, rainfall condition, migration information and consideration	$I = (BA \times SN) \times PBC$ PBC: $ra = r_1 + r_2 + r_3,\ ar = la + (ra \times oc),\ er = \frac{de}{100} + \frac{ge}{1000}$ BA: $PV(A,G,S,L,RC) = \frac{m(a,g,s,l,rc)}{p(a,g,s,l)}, BA = \frac{PV(a,g,s,l,rc)}{op}$ $SN = f(po)$
4. Economic models	Monetary, non- monetary, psychological costs, distance, income, unemployment, educational, population, urbanization, human capital investment	$ER(0) = \int_0^n [p_D(T)p_{ED}(t)Y_D(t)NR_D(t) - p_{EO}(t)Y_O(t)NR_O(t)]e^{-rt}dt - C(O)$ $\int_{j=g}^{n} (Y_{K'j} - C_{K'j})(t)e^{-rt}dt - \int_{j=g}^{n} Y_{K'j}(t)e^{-rt}dt = 0$
5. Modelling Migration and Regional Labor Markets: an Application of the New Economic Geography Model RHOMOLO	Labour market, wage, unemployment, distance	$\ln\left(\frac{s_{od}}{s_{oo}}\right) = \beta_1 \ln(income_0) + \beta_2 \ln(income_d) + \beta_3 \ln(distance_{od}) + \beta_4 \mathrm{I}(international_{od}) + \beta_5 \ln\left(s_{od\vert c_d}\right) + (\xi_{od} - \xi_{oo})$
Mathematical Modelling of Migration (continue)		
Model	**Variables**	**Equations**

6. Migration Modelling by Markov Chain Method	Perpetuation of migration; population flows	$P^{(n-1,n)} = \begin{bmatrix} \frac{f_{11}^n}{p_1^{n-1}} & \frac{f_{12}^n}{p_1^{n-1}} & \cdots & \frac{f_{1N}^n}{P_1^{n-1}} \\ \vdots & & \ddots & \vdots \\ \frac{f_{N1}^n}{p_N^{n-1}} & \frac{f_{N2}^n}{P_N^{n-1}} & \cdots & \frac{f_{NN}^n}{p_N^{n-1}} \end{bmatrix} = \left[p_{ij}^{(n-1,n)}\right]$
7. Statistical models: Time series and Multiple regression analysis	Wage, unemployment, population density, crop production	$\frac{\partial n}{\partial t} = \int p\big(q(x-z,t)\big)\lambda\big(\mathrm{q}(\mathrm{x}-\mathrm{z},\mathrm{t})\big)\mathrm{n}(\mathrm{x}-\mathrm{z},\mathrm{t})\rho(z)dz - p\big(q(x,t)\big)\lambda\big(\mathrm{q}(\mathrm{x},\mathrm{t})\big)\mathrm{n}(\mathrm{x},\mathrm{t}) + [1-p(q)]rn\left(1-\frac{n}{K(q)}\right)$
8. The Human Capital model	Labour market, wage, mobility costs, age, education, marital status	$PV_{ij} = \sum_{t=1}^{n} \frac{1}{(1+r)^t}\left[\left(E_{jt}-C_{jt}\right)-\left(E_{it}-C_{it}\right)\right]$
9. Models of Return Migration	Age, asset, GDP	$V(A,G,Y,\lambda, S,\eta_S\eta_R) = \max\{V^{Stay}(A,G,Y,\lambda)+\eta_S, V^{Return}(A,G,Y,S) + \eta_S\}$ $V^{Stay}(A,G,Y,\lambda) = u^{Stay}(G,\lambda,c^S) + \beta E_{Y,\acute{\lambda}\mid Y,\lambda,\eta_S,\eta_R}, V\big(A+1,G+1,\acute{Y},\acute{\lambda}\big)$ $V^{Return}(A,G,Y,S) = \max u^{Return}(A-G,c^R) + \beta E_{\acute{Y}\mid Y} V^{Return}\big(A+1,G,\acute{Y},\acute{S}\big)$

6. CONCLUDING REMARKS

Migration becomes part of local culture and it makes migration more and more accessible to all levels of the population. The growing body of work in the development of migration models over the past decades shows the importance of this subject in research community. However, several challenges and opportunities for further research are still remained. The main goals of this paper were to critically review the theories, qualitative structural modelling and mathematical modelling of migration.

A number of researches have focused on the causes and impacts of migration which are the basis of migration modelling. The synthesis in the previous section showed, causes of migration can be classified into seven factors; extreme climate events, education, marriage, social, economic, technology, and political issues, and destination effects such as; Economic, social, environmental, cultural, and occupational opportunities.

The models analysed in this paper included some of these variables. Migration theories can be classified according to the level they focus on; macro-level, micro-level and meso-level. Macro- level theories including neoclassical, world system, Zelinkey's hypothesis, and dual labour market theory mostly focus on economic, social, employment, capitalism, political, globalization, modernization and demographic variables. Micro-level theories such as Lee's push and pull theory, human capital theory, neoclassical micro-level theories, new economics of migration (NEM) theory, and the new economics of labour migration (NELM) consider the variables similar to macro-level but in individual choices. The meso-level theories are in between the micro and macro level and they are theoretical and practical interplay between social structure and human agency. Dual labour market, world system, and cumulative and circular causation model are in this category.

Various qualitative structural modelling were reviewed and grouped as; Immigration and acculturation, conceptual modelling of migration by E-R diagram, models of migration for adaptation and response in climate change, exploring the link between climate change and migration, and a conceptual framework for the "drivers of migration". To allow for easier comparison of similar studies, we presented all in the table 2. However, as this literature is still fairly sparse, each model focused on different variables. In general, cultural, political, economic, social, education, employment, political, demographic, demographic, environmental, and climate variables were applied in these conceptual models.

Mathematical models of migration were analysed in the context of variables of type of the equations. Table 3 presents an overview of the mathematical modelling. Both the modified gravity model and modelling migration regarding regional labour markets have a logarithm type of equation. The modified gravity model includes variables such as; population, distance, income, unemployment, urbanization, climatological variables and taxes. Looking at modelling migration regarding regional labour markets, labour market, wage, unemployment, and distance variables are covered by this model. Three models had integral/differential type such as: migration modelling based on adaptation to climate change, economic models, statistical and time series models. Migration modelling based on adaptation to climate change involves vulnerability, adaptive capacity, frequency, longevity, and climate factors. Economic models emphasize on monetary, non- monetary, psychological costs, distance, income, unemployment, educational, population, urbanization, and human capital investment variables. Statistical time series models consider wage, unemployment, population density, and crop production factors. Model of agent migration adaptation to rainfall change includes a variety of variables such as; adaptation behaviours, subjective norm, perceived behavioural control; rainfall assets, livestock asset, occupation, experience and general information about migration, age, gender, marital status, rainfall condition, migration information and consideration. Markov chain models make link between perpetuation of migration and population flows and have a matrix type. Human capital model highlights the role of labour market, wage, mobility costs, age, education and marital status variables on modelling migration and involves economic type of equations. The last type of optimization models allow for return migration but also concentrate on age, asset and GDP parameters.

The synthesis in the previous section showed that there is no unanimity over the modelling of migration. One of the reasons of the absence of one global model on migration is the absence of unified theory of migration, which could become a basis for modelling, as well as the absence of a common approach in terminology of migration. Comparing and contrasting all above discussed, a combination of "economic models" and "model of agent migration adaptation to rainfall change" seems to offer a better way of modelling migration involving climate factors, education, marriage status, social, economic and technology variables. Only political issues should be added as a supplementary variable, so in this regard the developed model can cover all above cause of migration simultaneously and can be as a comprehensive migration model.

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