Max Planck Institute for Demographic Research

An agent-based decision model of migration, embedded in the life course

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The problem

7 March 2013 Last updated at 11:17 GMT

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Prof says his '13,000 EU migrants' report 'misinterpreted'

By Ed Lowther
Political reporter, BBC News

Romanian Immigration Is Up - But Ukip's Prediction Was Off By A Pretty Long Way

The Huffington Post UK | By Jessica Elgot

Posted: 13/08/2014 16:34 BST | Updated: 13/08/2014 16:59 BST

Published online 26 July 2010 | Nature | doi:10.1038/news.2010.375

News

Mexican 'climate migrants' predicted to flood US

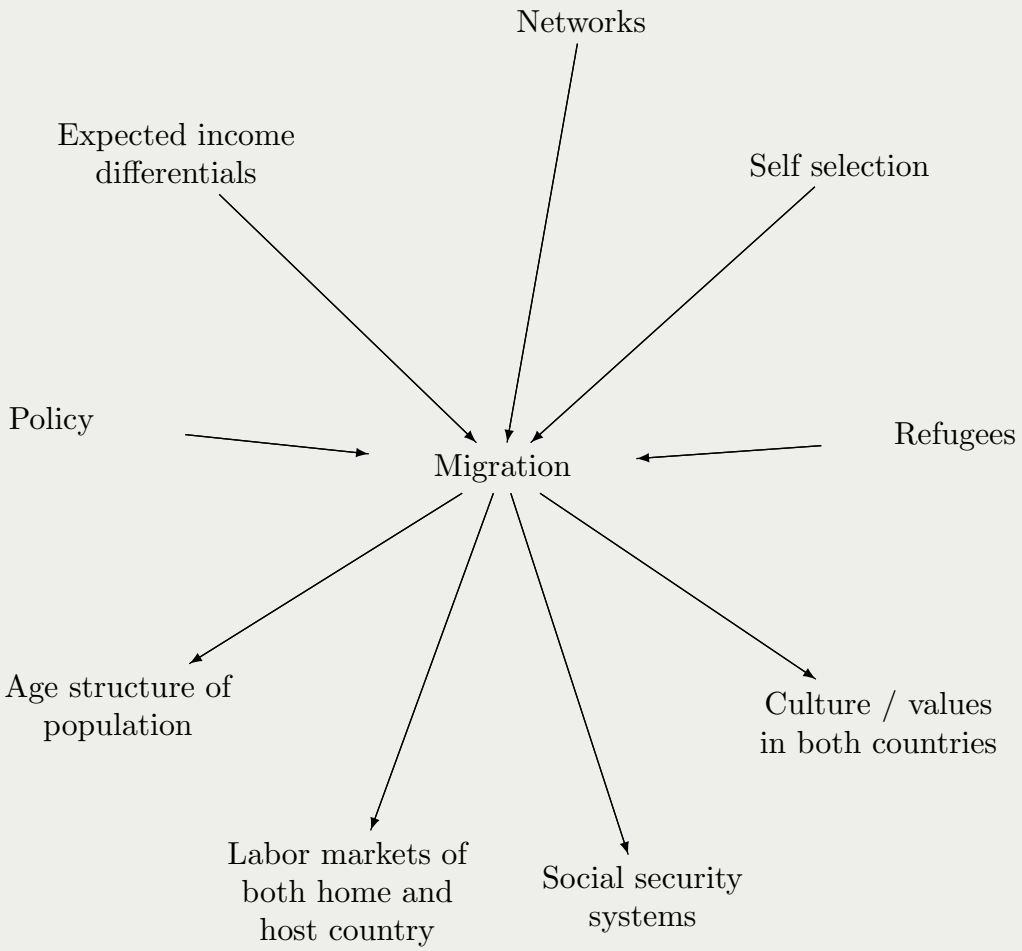
A tenth of Mexico's population could surge north to escape climate-triggered crop failures, study claims.

Zoë Corbyn

Gallup World Poll: 14 percent of adults worldwide desire to emigrate (2005).

About 3 percent of people emigrate at some point in their life (IOM 2010).

The phenomenon of international migration



Tools to understand and predict migration I

Statistical models

- Time series methods (Gorbey et al. 1999)
- Macro-level econometric models (Dustmann et al. 2003)
- Bayesian forecasting (Bijak 2011)
- Extrapolation from stock data (Abel and Sander 2014)
- Micro-level
  - Discrete time event-history analysis (Massey and Espinosa 1997)
  - Survival analysis (Lindstrom 1996)

Microsimulation

Discrete time (Massey and Zenteno 1999) vs. continuous time (Rephann and Holm 2004)

Tools to understand and predict migration II

Theoretical models

- Mainly econ: Sjaastad (1962), Harris and Todaro (1970), Borjas (1987), Stark and Bloom (1985)...
- Gravity theory (Stewart 1941)
- Push-pull theory (Lee 1966)
- Networks and social capital

Qualitative research

Field studies, In-depth surveys,...

Agent-based models

Klabunde (2014), Kniveton et al. (2011)...

Our approach

Idea: Combine ‘statistical individual’ (Courgeau 2012) and ‘agent’

Statistical model
Multistate survival analysis on the MAFE data set

Microsimulation
Synthetic life courses prescribed by estimated event rates

Theoretical model for migration behavior
Process Theory of Planned Behavior (Ajzen 1991 / Willekens 2014)

Agent-based model
Putting it all together, adding spatial dimension and interaction

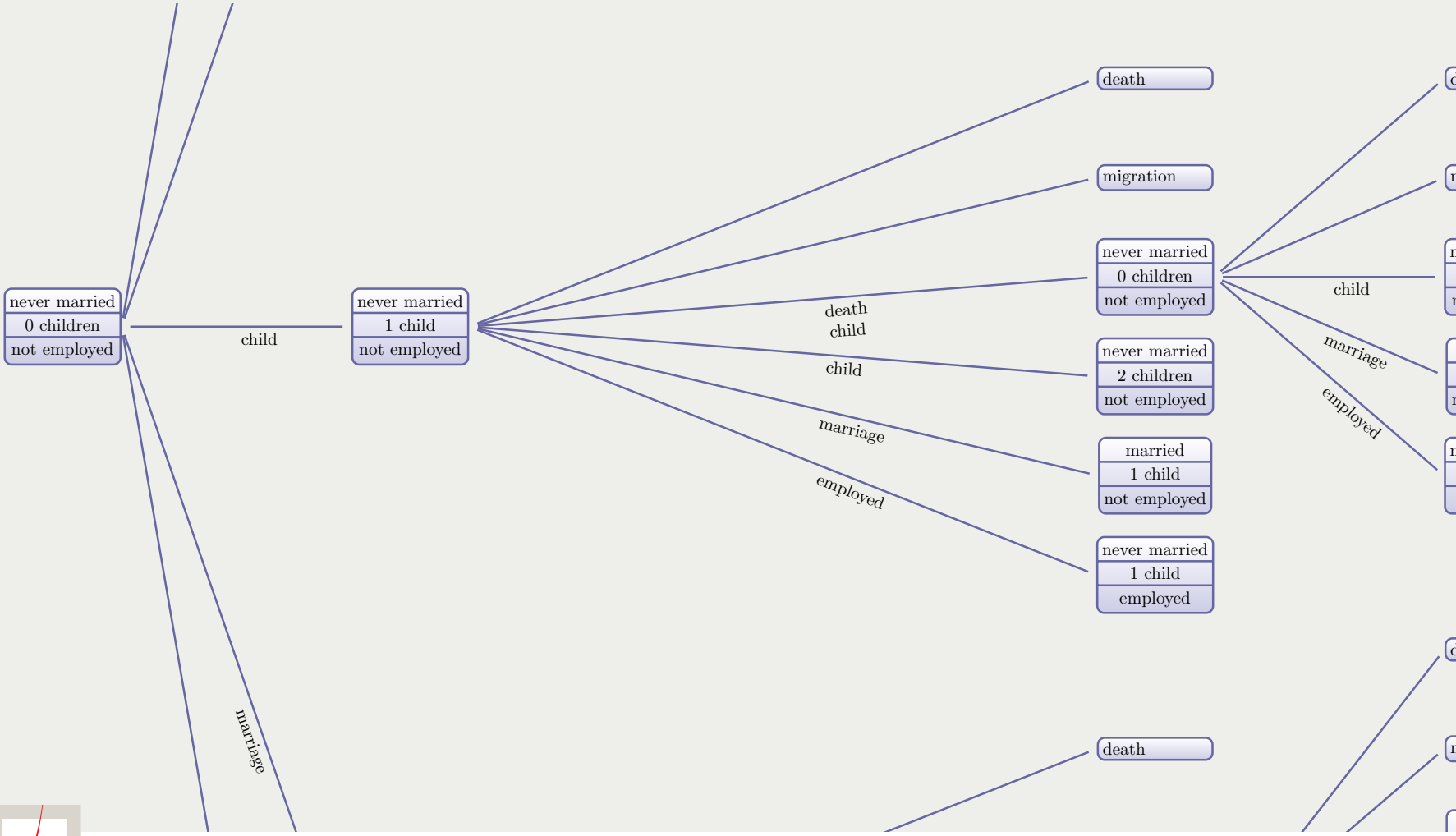
The MAFE Senegal data set I

- http://mafeproject.site.ined.fr/
- Coordinated by INED; Cooperation of 9 institutions
- Event-history microsurvey, similar to the Mexican Migration Project
- Focus: Migration flows between Senegal and France, Italy, Spain
- Household survey: 1141 households in Senegal; basic information on 12350 individuals
- Biograph survey: 1062 in Senegal, ca. 200 in each of France, Italy, Spain
- Oversampling of migrant households (household survey), return migrants and partners of migrants (Biograph survey)

The MAFE Senegal data set II

- Senegal: 3-stage stratified random sample from Dakar region
  - 10 strata of equal size (according to the % of households with migrants within each of them)
  - 60 districts were selected (6 per strata)
  - 22 households were randomly selected in each of the 60 districts
  - Two strata: the households with migrants and those without
  - Households equally divided: 11 households with migrants and 11 without
  - Total of 1320 households (449 with migrants and 841 without)
  - Completed household surveys: 1141.
- In Italy and France: selected public places and snowballing
- Spain: Sampling from the Municipal Population Register

Multistate model I



Multistate model II

- Life histories are realisations of a continuous-time Markov process
- Times at which events occur are random
- Waiting times to events stem from an exponential distribution
- Rate of transition out of the current state is the parameter of this distribution

Multistate model III

- Different new states are competing risks with a transition rate specific to the new states
- Transition rates vary with age (and possibly other covariates)
- Occurrence-exposure rates; piecewise-constant in age-interval
- implemented with the R package ‘Biograph’ (Willekens 2013)

Transitions observed - women

	S	Ch	M	E	D	W	Total	Censored	TOTAL
S	0	99	635	74	0	0	808	60	868
Ch	0	1591	83	113	122	87	1996	371	2367
M	0	636	0	67	44	15	762	65	827
E	0	0	0	0	0	0	0	273	273
D	0	32	77	11	0	0	120	46	166
W	0	8	32	8	0	0	48	54	102
Total	0	2366	827	273	166	102	3734	869	4603

Transitions observed - men

	S	M	E	D	W	Total	Censored	TOTAL
S	0	458	193	0	0	651	147	798
M	0	126	135	105	21	387	271	658
E	0	0	0	0	0	0	333	333
D	0	66	4	9	1	80	34	114
W	0	8	1	0	0	9	13	22
Total	0	658	333	114	22	1127	798	1925

Challenges: Polygamy

- Of 590 women married at survey date (2008)
  - 390 were the only wife
  - 129 had one co-wife, 61 had 2 co-wifes, 9 had 3 co-wives and one had 13 co-wives
  - i.e. 33.9 % of married women live in polgamous marriages
- For men at survey date:
  - 17.3% of married men have more than one wife

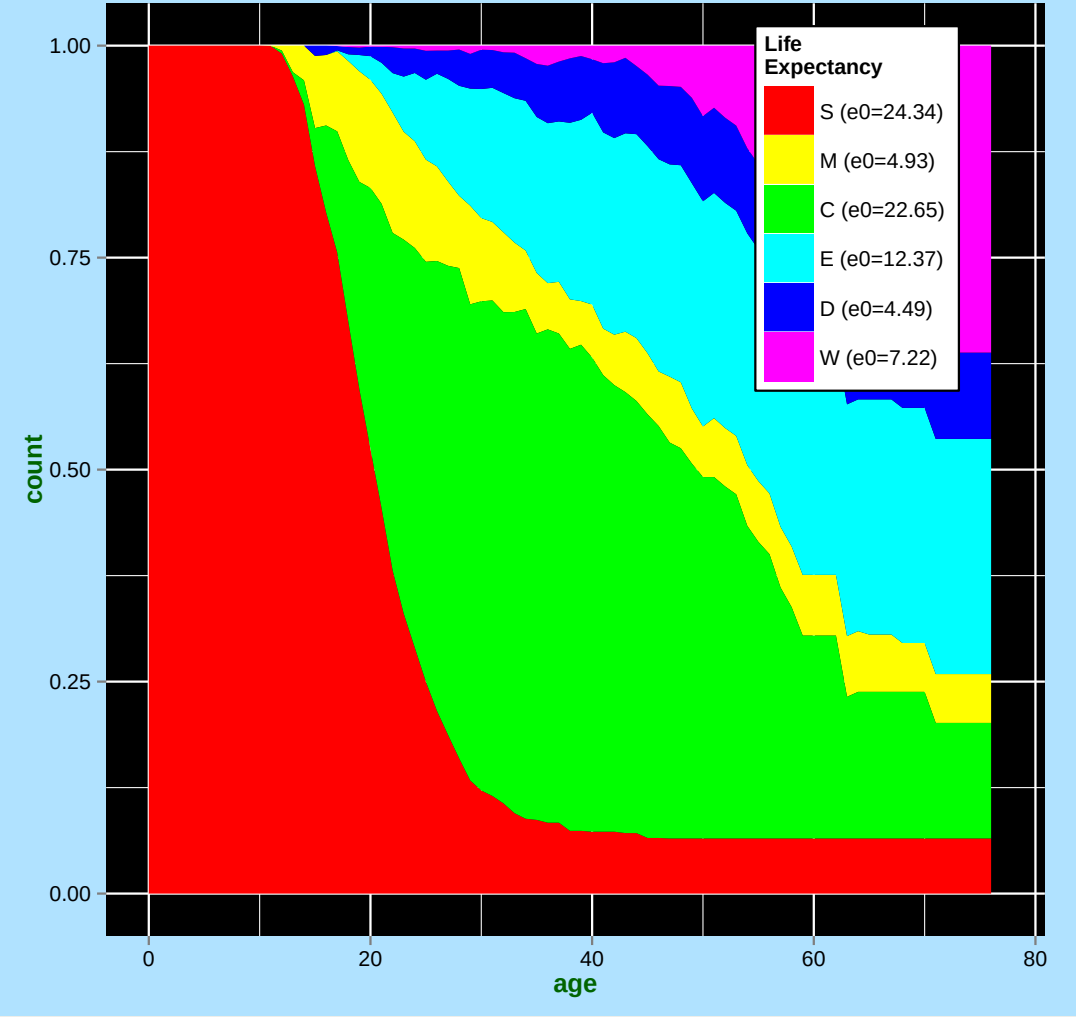
Challenges: Non-representativity, weighting

- Only observations in Dakar region
  - 26% of population, but only 0.28% of land surface
  - internal migration to Dakar
  - in Dakar 26% below Senegalese poverty threshold; rest of country: between 40 and 77 % (ANSD Senegal, 2011)
  - More than 50% of public spending for Dakar (World Bank 2012)
- Migrants oversampled
  - Weights for estimation of rates and descriptive statistics
  - weighting factor: inverse of sampling probabilities at each stage, normalized and corrected for non-response

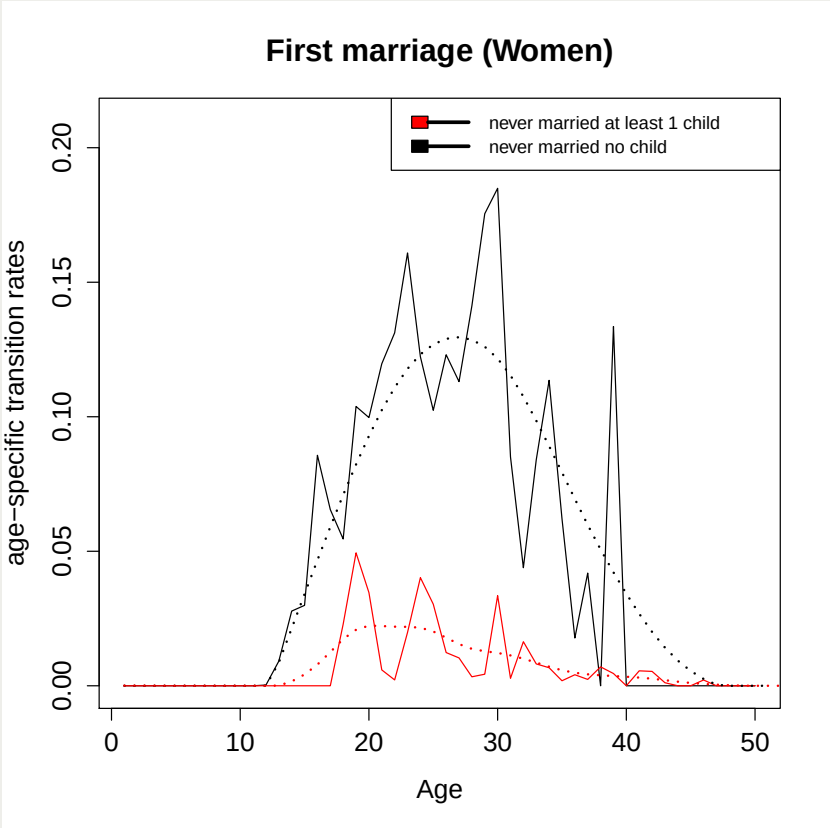
Challenges: Income, Truncation

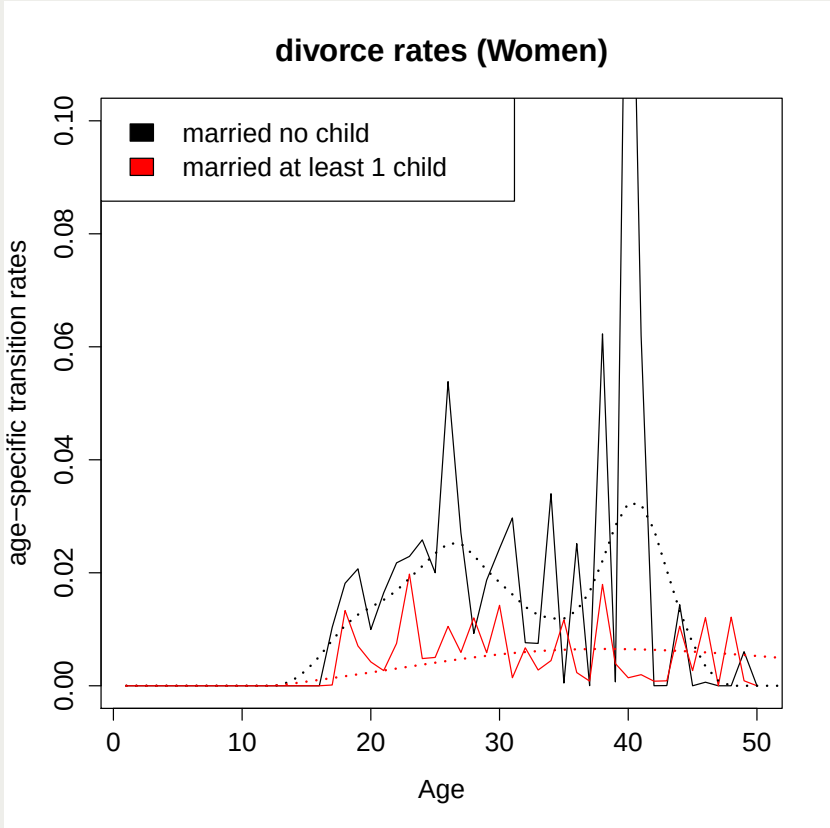
- More than 50% missing observations for sources of income
- Any virtual cohorts or period-populations constructed from the retrospective data are conditioned upon survival to the year 2008
- –> Other sources for mortality rates

Expected duration in different states



Marriage and divorce

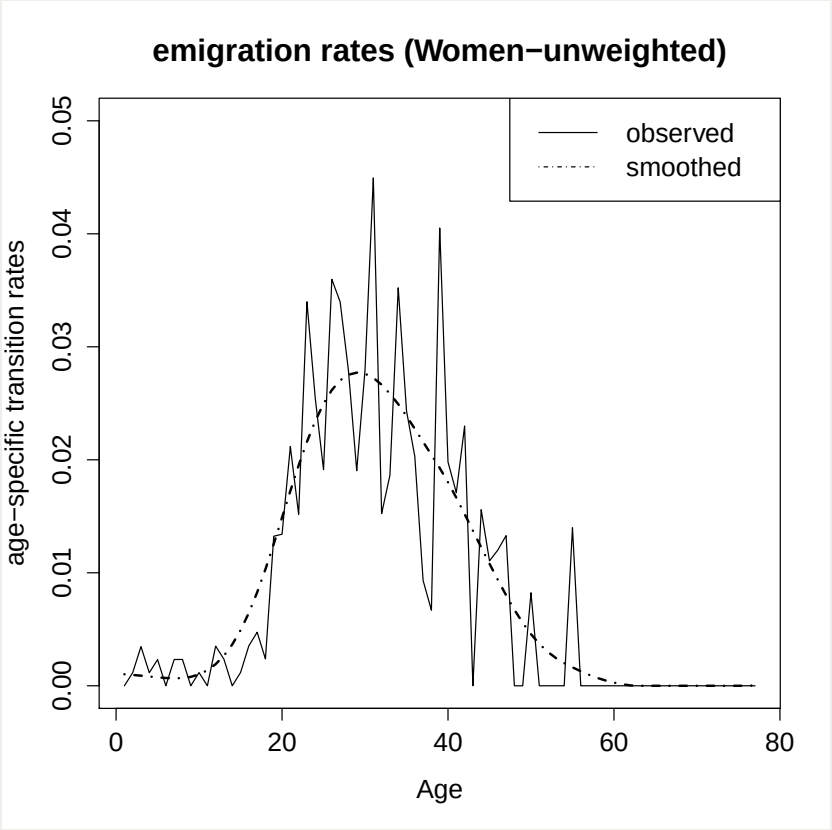


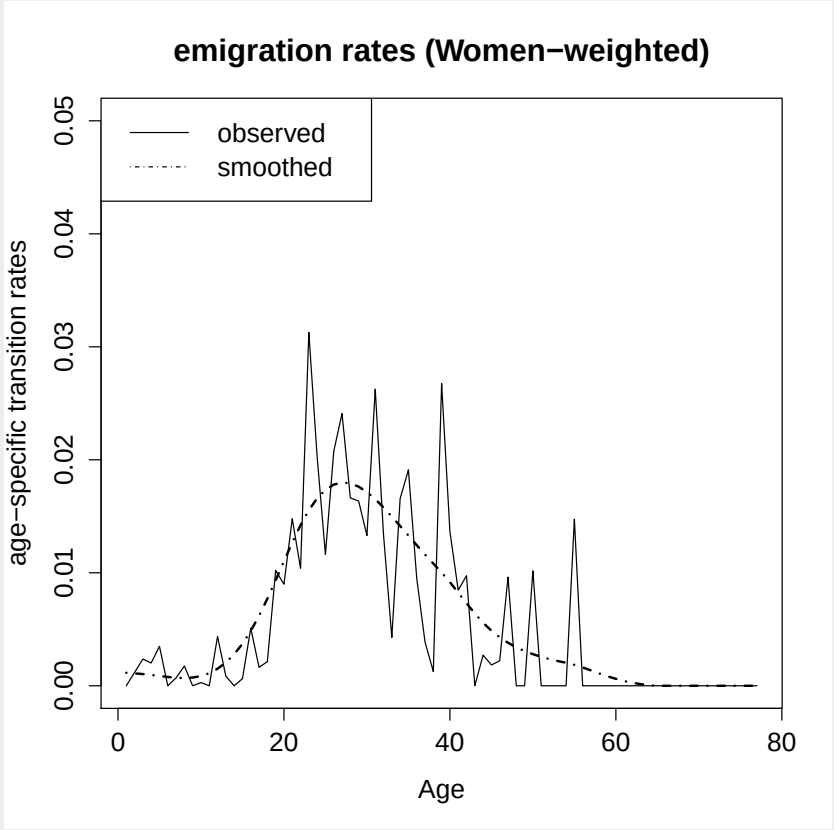


Fertility


Transition to first child (Women)
married
single
smoothed−married
smoothed−single
age−specific transition rates
0.0
0.1
0.2
0.3
0.4
0.5
0
10
20
30
40
50
Age

Emigration rates





State space

Nr.	State	Possible new states
1	(NM, 0, NE)	(M, 0, NE), (NM, 1, NE), (NM, 0, E), Mig, De
2	(M,0, NE)	(W, 0, NE), (D, 0, NE), (M, 1, NE), (M, 0, E), Mig, De
3	(NM,1,NE)	(M, 1, NE), (NM, 0, NE), (NM, 2, NE), (NM, 1, E), Mig, De
4	(NM, 0, E)	(M, 0, E), (NM, 1, E), (NM, 0, NE), Mig, De
5	(W, 0, NE)	(M, 0, NE), (W, 1, NE), (W, 0, E), Mig, De
6	(D, 0, NE)	(M, 0, NE), (D, 1, NE), (D, 0, E), Mig, De
7	(M, 1, NE)	(W, 1, NE), (D, 1, NE), (M, 0, NE), (M, 2, NE), (M, 1, E), Mig, De
8	(M, 0, E)	(W, 0, E), (D, 0, E), (M, 1, E), (M, 0, NE), Mig, De
9	(NM, 2, NE)	(M, 2, NE), (NM, 1, NE), (NM, 3, NE), (NM, 2, E), Mig, De
10	(NM, 1, E)	(M, 1, E), (NM, 0, E), (NM, 2, E), (NM, 1, NE), Mig, De
11	(W, 1, NE)	(M, 1, NE), (W, 0, NE), (W, 2, NE), (W, 1, E), Mig, De
12	(W, 0, E)	(M, 0, E), (W, 1, E), (W, 0, NE), Mig, De
13	(D, 1, NE)	(M, 1, NE), (D, 0, NE), (D, 2, NE), (D, 1, E), Mig, De
14	(D, 0, E),	(M, 0, E), (D, 1, E), (D, 0, NE), Mig, De
15	(M, 2, NE),	(W, 2, NE), (M, 1, NE), (D, 2, NE), (M, 3, NE), (M, 2, E)
16	(M, 1, E),	(W, 1, E), (D, 1, E), (M, 0, E), (M, 2, E), (M, 1, NE), Mig, De
17	(NM, 3, NE)	(M, 3, NE), (M, 2, NE), (NM, 3+, NE), (NM, 3, E), Mig, De
18	(NM, 2, E)	(M, 2, E), (NM, 1, E), (NM, 3, E), (NM, 2, NE), Mig, De
19	(W, 2, NE)	(M, 2, NE), (W, 1, NE), (W, 3, NE), (W, 2, E), Mig, De
20	(W, 1, E)	(M, 1, E), (W, 0, E), (W, 2, E), (W, 1, NE), Mig, De
21	(D, 2, NE)	(M, 2, NE), (D, 1, NE), (D, 3, NE), (D, 2, E), Mig, De
22	(D, 1, E)	(M, 1, E), (D, 0, E), (D, 2, E), (D, 1, NE), Mig, De
23	(M, 3, NE)	(W, 3, NE), (D, 3, NE), (M, 2, NE), (M, 3+, NE), (M, 3, E), Mig, De
24	(M, 2, E)	(W, 2, E), (D, 2, E), (M, 1, E), (M, 3, E), (M, 2, NE), Mig, De
25	(NM, 3, E)	(M, 3, E), (NM, 2, E), (NM, 3+, E), (NM, 3, NE), Mig, De
26	(W, 3, NE)	(M, 3, NE), (W, 2, NE), (W, 3+, NE), (W, 3, E), Mig, De
27	(W, 2, E)	(M, 2, E), (W, 1, E), (W, 3, E), (W, 2, NE), Mig, De
28	(D, 3, NE)	(M, 3, NE), (D, 2, NE), (D, 3+, NE), (D, 3, E), Mig, De
29	(D, 2, E)	(M, 2, E), (D, 1, E), (D, 3, E), (D, 2, NE), Mig, De
30	(W, 3, NE)	(M, 3, NE), (W, 2, NE), (W, 3+, NE), (W, 3, E), Mig, De
31	(D, 3, NE)	(M, 3, NE), (D, 2, NE), (D, 3+, NE), (D, 3, E), Mig, De
32	(M, 3, E)	(W, 3, E), (D, 3, E), (M, 2, E) (M, 3+, E), (M, 3, NE), Mig, De
33	(W, 3, E)	(M, 3, E), (W, 2, E), (W, 3+, E), (W, 3, NE), Mig, De
34	(D, 3, E)	(M, 3, E), (D, 2, E), (D, 3+, E), (D, 3, NE), Mig, De

Synthetic life courses

- *Micsim* Package (Zinn 2014)
- Synthetic initial population derived from survey population
- Synthetic life courses: described by a non-homogeneous continous-time Markov process
- Transition rates from MAFE
- Waiting times drawn from corresponding distributions, one for each possible new state
- Event with the shortest waiting time occurs (competing risks)
- All transitions simulated except migration (decision model)

Migration decision model: Theory of planned behavior

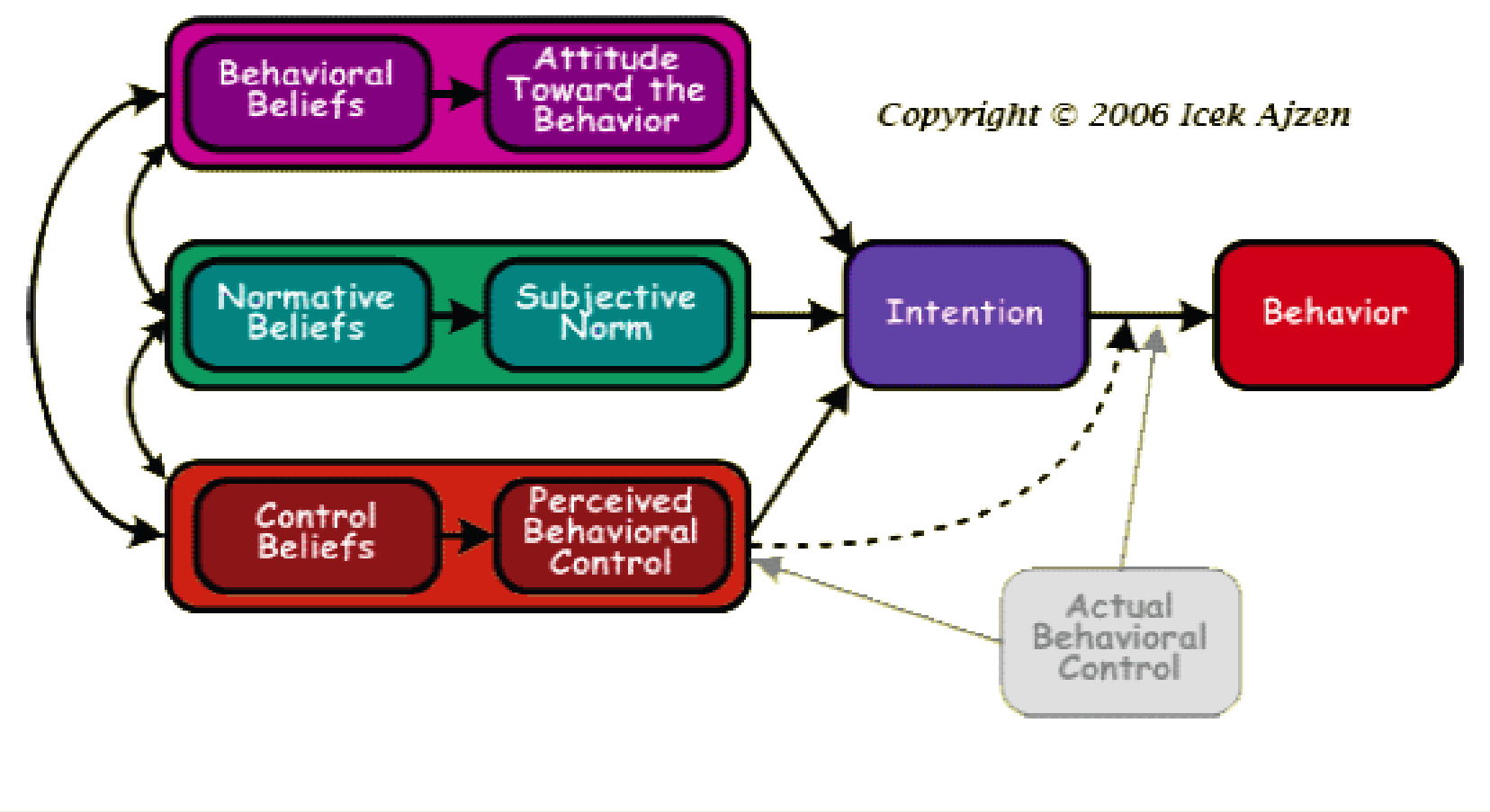


Figure: Fishbein and Ajzen (2010)

TPB applied to migration I

- See also: De Jong (2000), Van Dalen and Henkens (2008), Gubhaju and De Jong (2009)
- In our model: Agents pursue happiness, influenced by income and being close to family
- Attitude:

$$A_{i,t} = ew_{i,t} bw_{i,t} + ef_{i,t} bf_{i,t} \tag{1}$$

where ew: evaluation of higher income in the host country, bw: subjective probability to achieve higher income, ef: evaluation of family reunification, bf: subjective probability to achieve familiy reunification.

TPB applied to migration II

- Evaluation of higher income in the host country:

$$ew_{i,t} = a_1 c_{h,t} + a_2 w_{i,t} + a_3 (A_{h,t} + K_{h,t}) \quad (2)$$

  where $c_{h,t}$: capital of i's household, $w_{i,t}$: agent's wage earnings, $A_{h,t}$: number of adults in the household, $K_{h,t}$: number of children, a_1, a_2 and a_3: parameters

- Subjective probability to achieve higher income through migration: proportion of agent's network neighbors who had higher income after migration than the agent's current income
- Evaluation of family reunification: $ef_{i,t} = a_4 M_{i,t}$, where $M_{i,t}$ is the number of previous household members who have migrated and a_4 is a fixed parameter
- Subjective probability of family reunification: 1

TPB applied to migration III

- Social norms: prop. of network neighbors who ever migrated
- Perceived behavioural control:

$$PBC_{i,t} = -(pb_t cb_{i,t} + pc_{i,t} cc_{i,t}) \tag{3}$$

where pb_t: importance of border enforcement, $cb_{i,t}$: subjective probability that border enforcement will influence the agent's migration, $pc_{i,t}$: importance of the migration cost, $cc_{i,t}$: subjective probability that the migration cost could preclude the agent's migration.

- Border enforcement pb_t: exogenously given and known; $cb_{i,t}$: proportion of failed migration attempts of the agent's network neighbors; $pc_{i,t}$ exogenous and constant
- $cc_{i,t}$: proportion of periods in which the agent would not have been able to afford the migration cost

TPB applied to migration IV

- Intention:

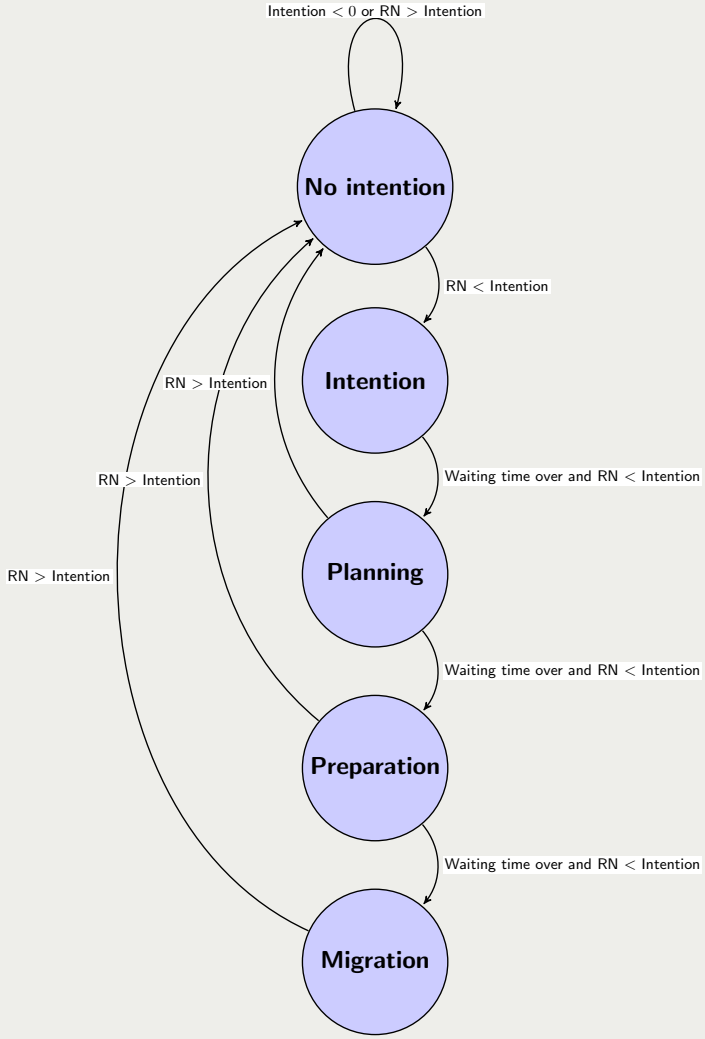
$$I_{i,t} = a_5 A_{i,t} + a_6 SN_{i,t} + a_7 PBC_{i,t} \tag{4}$$

  where a_5, a_6 and a_7 are parameters.
- Attitude and social norms: positive values, PBC is negative
- Agent's intention $I_{i,t}$ can be in the range $[-\inf, +\inf]$.

Why the TPB is reasonable for the migration decision

- Established theory from social psychology
- Empirically relevant predictor of behavior (see Armitage and Conner 2001)
- Far-reaching consequences
- High level of uncertainty
- Enables rigorous inclusion of factors influencing beliefs
- Attrition during the decision process and time dimension (Willekens 2014)

Tranforming the TPB into a process theory



Continous-time Agent-based model: Overview I

- Microsimulation determines demographic events and waiting times for each agent
- Autonomous agents make migration decision following TPB
- Also ABM is continuous time (milliseconds)
- Only eventful milliseconds are simulated
- Agents act when waiting times are over or triggered by actions of other agents
- Demographic events and transitions to new decision stages are competing risks

Continous-time Agent-based model: Overview II

- The following events happen in the order they are scheduled:
  - Births, deaths
  - Marriage, divorce
  - Transitions to employment and unemployment
  - Retirement
  - Update of intention to migrate
  - Drop out of decision stages and progress to next stage
  - Migration
- At the end of each day: Consumption
- At the end of each month: Employed agents receive wage

Continous-time Agent-based model: Overview III

- Agents live in households
- Income sharing in households
- Fixed network from birth
- Two stylized countries
- Two-dimensional grid
- No choice of exact location in this version

Demographic events

- From MAFE, via Micsim
- Agents ‘receive’ a moslty pre-determined life history; deterministic
- In this version: Marriage, fertility etc have impact on migration but not vice versa –> Questionable!
- Only covariates for rates: age and gender (later: educational level, parity)
- Due to marriage and household formation: Some demographic events happen deterministically

Network formation

- At birth, links are formed to
  - Parents, siblings
  - Other household members
  - All members of all households in the Moore neighborhood
- Links remain throughout life

Marriage market I

- Modelled after Zinn (2012)
- 6 months before marriage event is scheduled: agent joins marriage market
- Compatibility score: Logit estimation on MAFE data which predicts the probability to be married to an individual with given characteristics
- Every 2nd time an individual enters the marriage market: mating
- If there are agents whose scheduled marriage time has already passed, the agent with the earliest marriage time is chosen
- Otherwise, the person with the marriage time closest to the current date

Marriage market II

- This agent makes partner choice: Choose partner in marriage market with highest compatibility score
- Newly married agents form household

Divorce and widowhood

- Women experience divorce event
- Household dissolution
- Ex-husband is assigned new waiting time to re-marriage based on MAFE transition rate for divorced men of his age (may be infinite)
- Re-marriage
- Widowhood if partner dies
- Analogous: new waiting time to re-marriage

Income and consumption

- Employed agents receive wage at the end of the month
- All earnings are added to household capital
- Different wage distributions in the two countries
- In the host country: wage is increased by dw if the agent has network neighbors there
- Every day, household capital $c_{h,t}$ is updated after consumption:

$$c_{h,t} = c_{h,t-1} - A_{h,t}\frac{m_1}{30} - K_{h,t}\frac{m_2}{30} \tag{5}$$

where $A_{h,t}$: number of adults in the household; $K_{h,t}$: number of children; m_1: Adult monthly consumtion; m_2: Child monthly consumption

Migration decision

- Intention:

$$I_{i,t} = a_5 A_{i,t} + a_6 SN_{i,t} + a_7 PBC_{i,t} \tag{6}$$

- If intention is negative: agent drops out of decision process
- If intention is positive: value is transformed to a probability to move to the next decision stage:

$$prob_{i,t} = \frac{1}{1 + exp(-I_{i,t})} \tag{7}$$

- Agent makes a random draw from the interval $[0, 1]$
- If the value drawn is smaller than $prob_{i,t}$, the agent moves to the next decision stage
- Otherwise, the agent exits his current stage and moves back to the beginning of the decision making process

Moving between decision stages I

- Once an agent enters a new stage: rate of moving to the next stage is determined using an exponential survival model with the intention as the only idiosyncratic parameter
- Probability density function of the exponential distribution:

$$p(t; \lambda_{i,t}) = \lambda_{i,t} e^{-t\lambda_{i,t}} \tag{8}$$

- Expected waiting time: $1/\lambda_{i,t}$
- The idiosyncratic parameter $\lambda_{i,t}$ is:

$$\lambda i, t(\rho, I_{i,t}) = \rho e^{a_8 * I_{i,t}} \tag{9}$$

where ρ: baseline rate for an intention value of 0; $I_{i,t}$: intention computed in 6; a_8: parameter.

Moving between decision stages II

- Same for agents currently in the “no intention” stage
- Entering new decision stage in the migration decision process and experiencing a new demographic event are competing risks
- If a demographic event happens to an individual before the waiting time to the next decision stage is over:
- New intention value is computed right away after the demographic event to compute new waiting time for the next step
- Reason: demographic event can change the evaluation of the attractiveness and feasability of migration dramatically

Migration I

- Intention one more time, random draw
- If this random number is smaller than $prob_{i,t}$, the agent finally attemps migration
- Actual border control pb_t
- Agent's probability to successfully migrate $probm_{i,t}$ is determined as

$$probm_{i,t} = \frac{1}{1 + exp(-\frac{1}{pb_t})}, pb_t > 0 \quad (10)$$

- Random draw
- If successful: Agent changes location, becomes unemployed

Migration II

- If the agent is unmarried or the spouse is still in the home country: migrant still belongs to his former home country household (remittances)
- If the agent is married and the spouse migrated before him: Both spouses form new household in the host country
- If the migration attempt is unsuccessful the agent remains in the home country and moves back to the first decision stage.

Next steps

- Finish programming
- Finish estimating rates
- Allow for polygamous marriages?
- Iterative calibration procedure
- Ranges of paramters from MAFE; systematic sensitivity analysis
- Verify whether model produces empirical migration rates
- Most important model extension: Education
- What-if research questions can be answered

Conclusion

- TPB might help avoid wrong predictions
  - Attitude alone overpredicts migration
  - Change in policy has effect on PBC without affecting attitude. Not taking this into consideration underpredicts migration
  - Changes in attitudes and social norms take time; effects might be delayed
  - What counts is not actual probabilities, but subjective beliefs (Bounded rationality!)
- Hope: Combine state-of the art statistical analysis of life courses with module to handle interaction and non-linear decision-making –> better policy analysis and predictions

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