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Sustainable Resilience and the Spill-Over Effect

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Problem

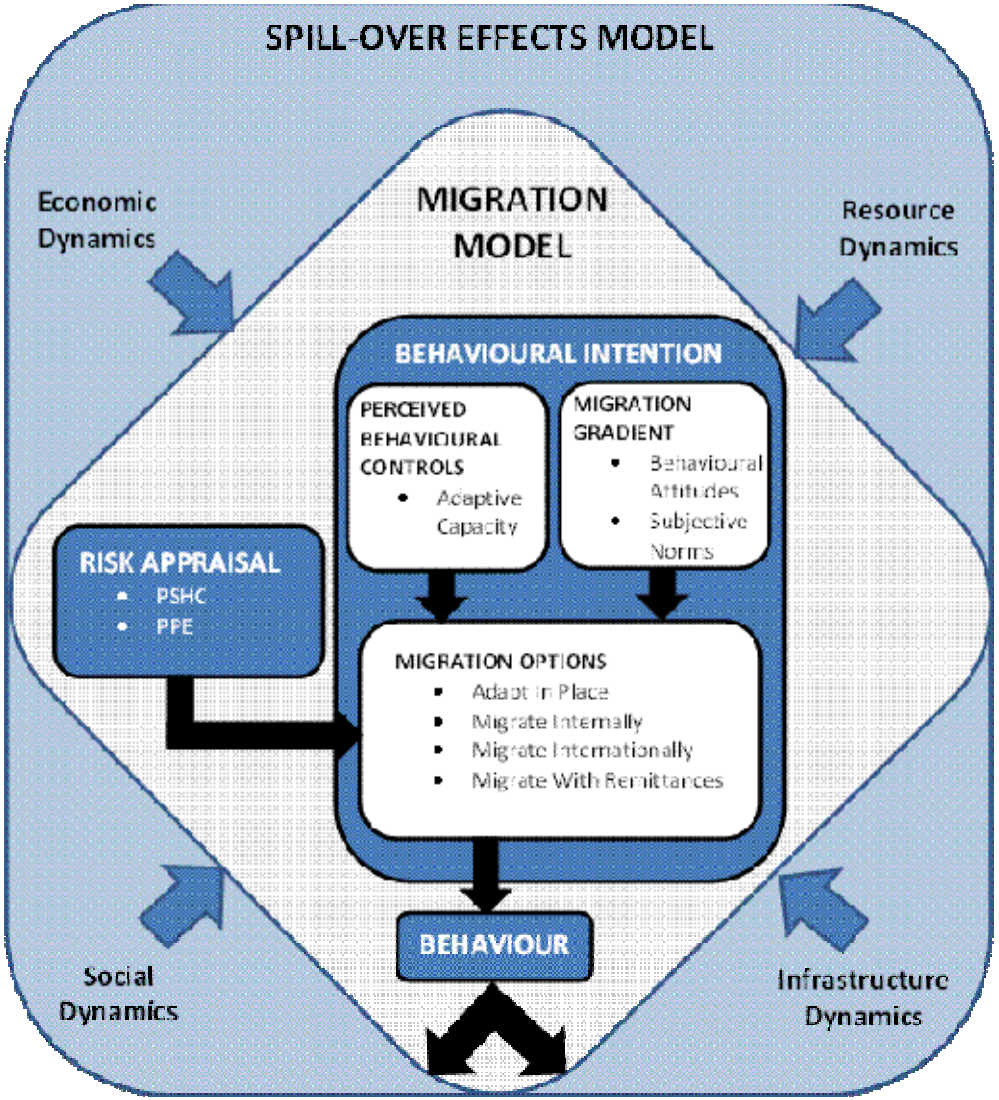
- Climate induced domino effect: reduced access/availability of key resources-leads to economic hardship-followed by social unrest, desperate emigration, and humanitarian crises.
- We term this the “spillover effect” as impacts are felt in adjoining nations as well as international markets and security.

Objectives

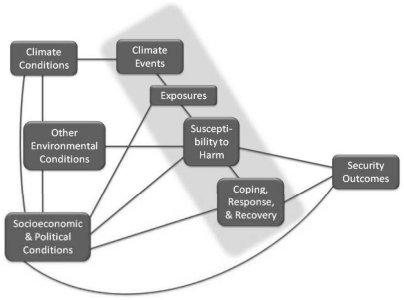
- Develop the theory and tools for quantitatively evaluating climate induced spillover:
  - Quantify the causes of climate induced spillover,
  - Identify nations at greatest risk,
  - Explore policy levers to assist nation states in adapting to effects of climate change, and
  - Establish a risk based assessment framework for determining what pre-emptive adaptive measures are most necessary when and where.

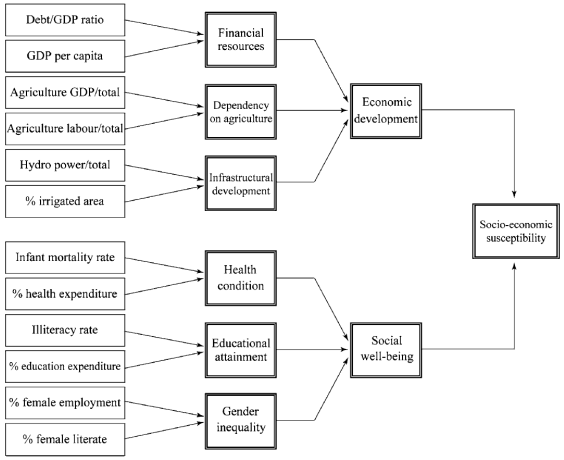
Approach

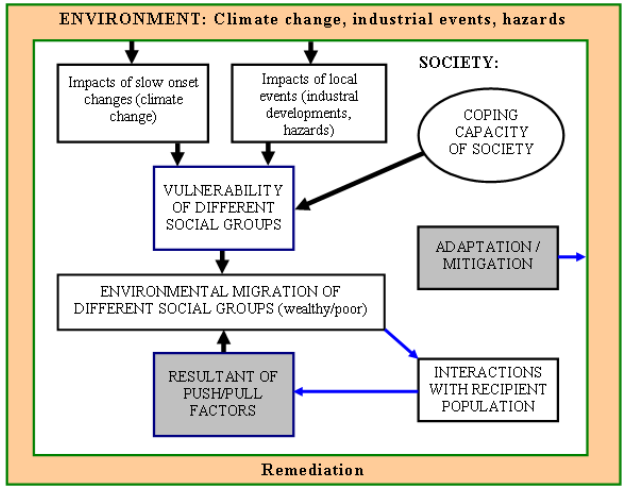
- Develop model of Spillover Effect
  - Hybrid system dynamics and agent-based architecture
  - Agent level model for response to environmental change
  - System dynamics model of the environmental factors that form cues to agents

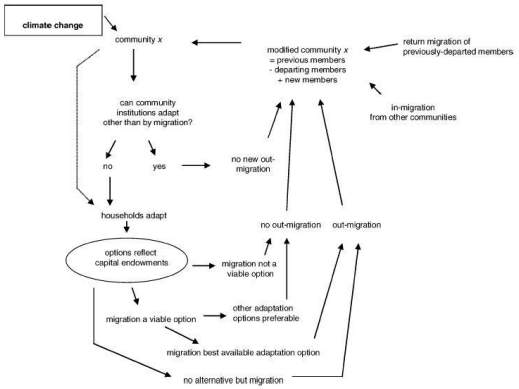


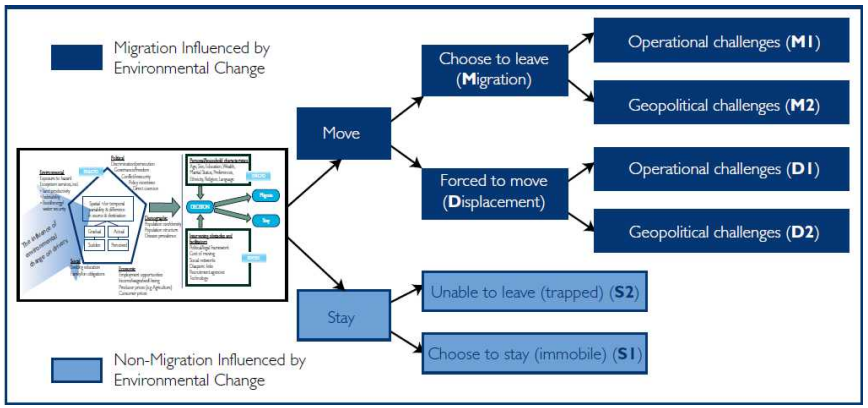
Modeling Human Migration

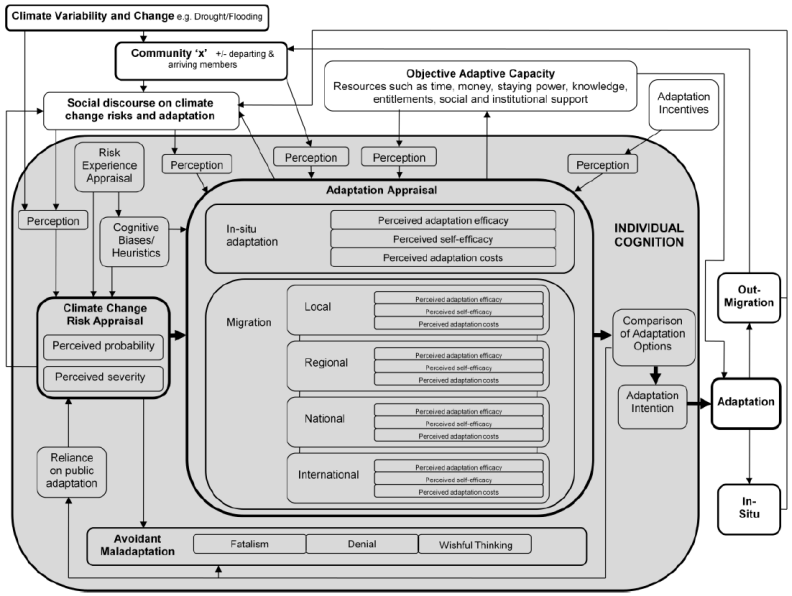






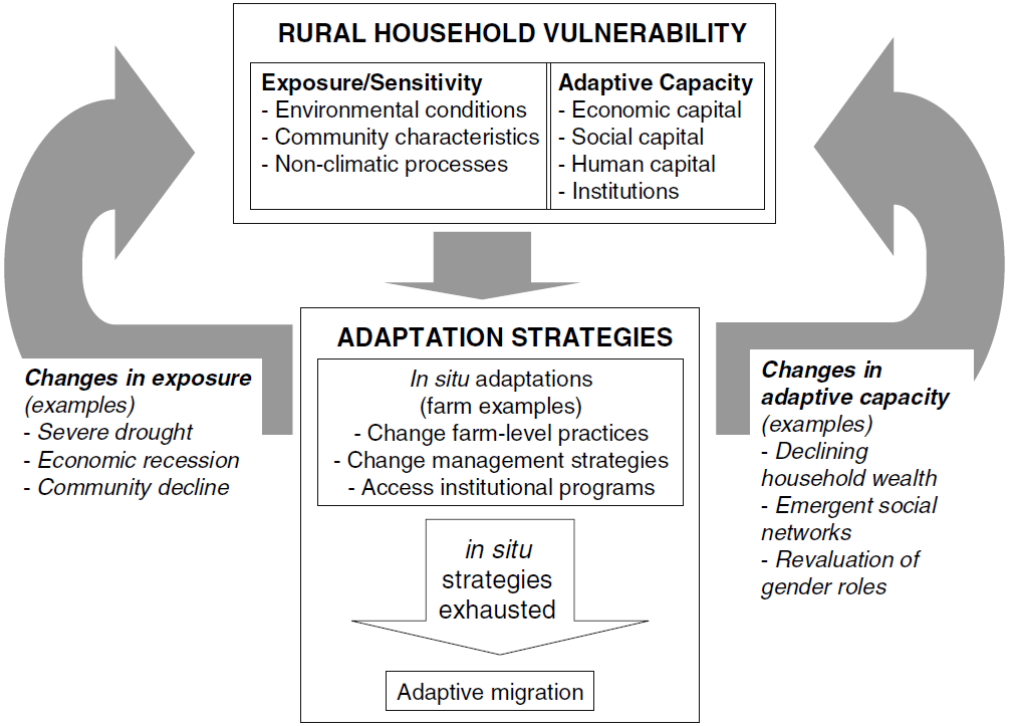






Modeling Human Migration

- Key concepts related to modeling human migration
  - ADAPTION STRATEGIES: there are other options besides migration and migration can take on many forms.
  - EXPOSURE: different events encourage different response (drought vs. flood).
  - EXPOSURE SENSITIVITY: sensitivity to an event varies as do the perceptions.
  - ADAPTIVE CAPACITY: capital constraints on adaptation strategy.
  - PUSH-PULL: perceived difference in quality of life between point of origin and destination.



Gilbert and McLeman (2010, 2011)

Modeling Human Migration

Migration equation cast in form of Fick's First Law of Diffusion

$$M_{i,j} = P_i \times AC_{i,j} \times \frac{dMP_{i,j}}{dx}$$

$M_{i,j}$ is the migration from country *i* to *j*

P_i is the cross section of population susceptible to migration

$AC_{i,j}$ is the adaptive capacity (savings, visa, network)

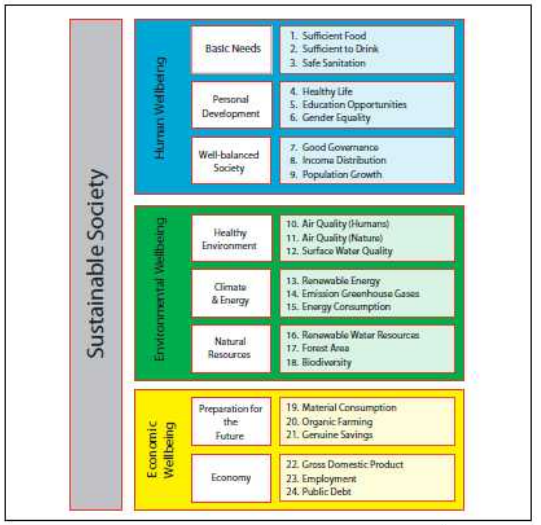
$MP_{i,j}$ is the migration potential (wage, violence, food difference)

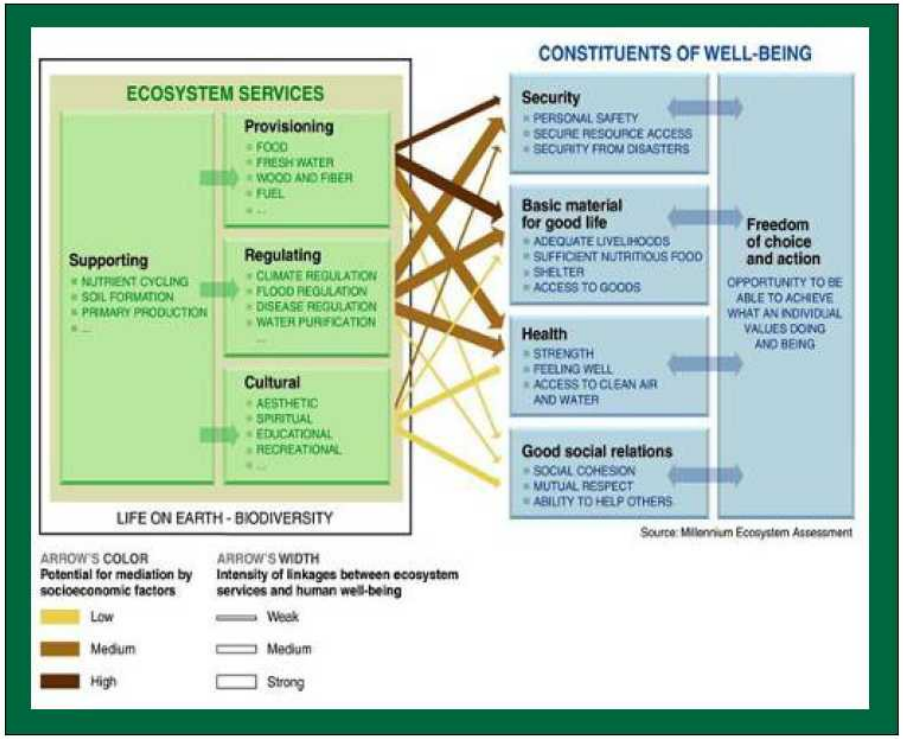
x is the distance between points

Modeling Human Migration

- Potential measures of *Migration Potential*
- UNDP's Broad Spectrum of Human Security Indicators:
  - Economic Security,
  - Food Security,
  - Health Security,
  - Environmental Security,
  - Personal Security,
  - Community Security, and
  - Political Security.
- Gradient between point of origin and destination

Sustainable Society Index





Modeling Human Migration

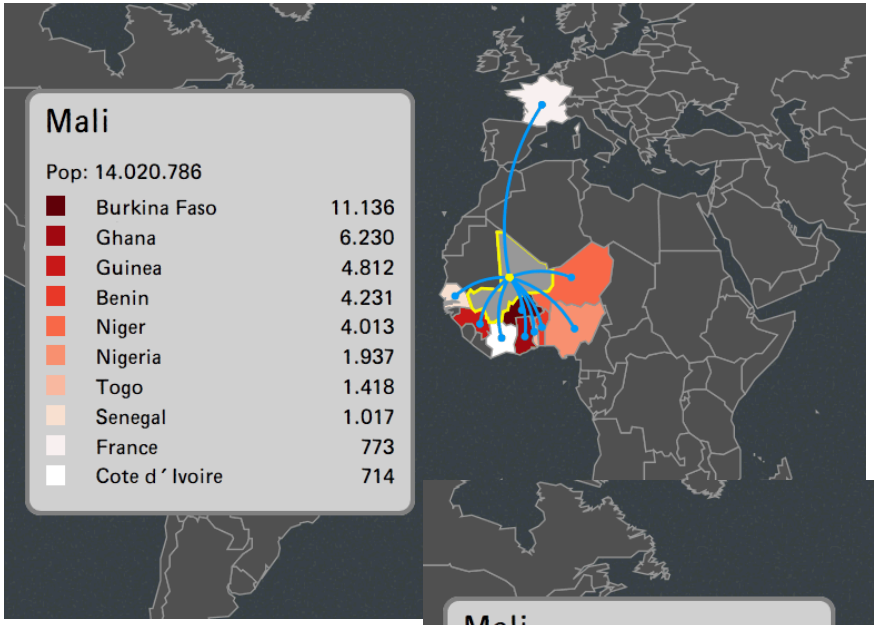
- *Adaptive Capacity* is the ability or capacity of a system to modify or change its characteristics or behavior so as to cope better with existing or anticipated external stresses
- Potential measures:
  - Financial capital – one must have the financial resources to fund a given adaptive option or to wait out an impact (e.g., savings)
  - Human capital - health, education, experience are key factors in allowing an individual to diversify in times of trouble (e.g., find a new job, apply new farming practice, adjust to a new culture/language). These also promote innovation toward new and different personal solutions
  - Social capital – the social network one has access to that will help them in times of trouble or group that can cooperate to accomplish changes that are beyond the reach of a single household
  - Physical/built capital – access to infrastructure and technology may be an important determinant in some cases
  - Governance – policies, information dissemination, border controls, insurance, etc. are key factors in enabling and organizing adaptation action

Modeling Human Migration

- Cross section of population who consider migration a viable option consists of two parts:
  - The proportion of population that falls in each of three threshold groups,
    - that population with a low *Migration Potential* and thus no strong driving force to migrate
    - that population that feels stress but can cope
    - that population with high *Migration Potential* and thus has been pushed beyond their coping capacity.
  - The personal choice aspect of the migration decision, depending on such factors as
    - Gender
    - Age
    - Community
    - skill level, and
    - past migration experience.

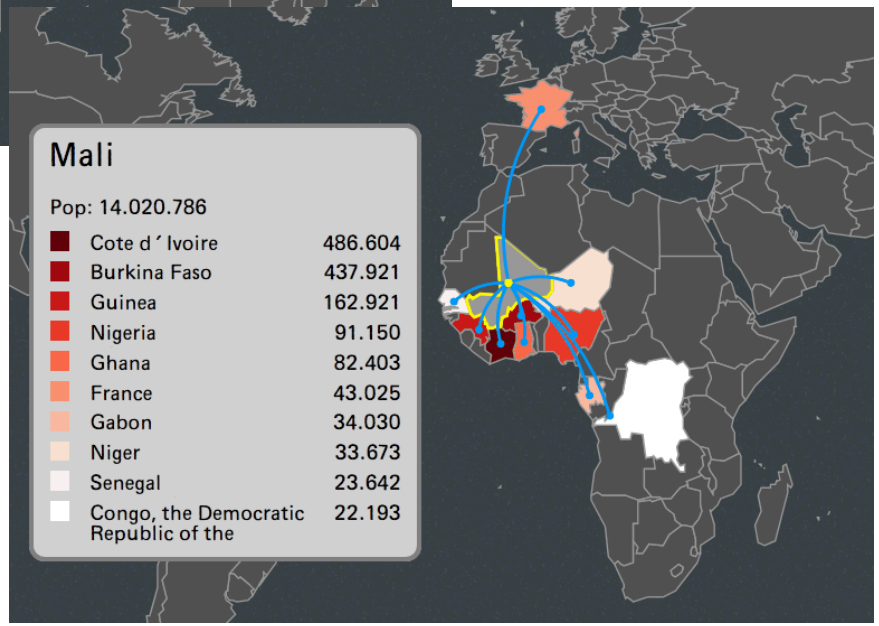
Case Study: Mali

In Migration



www.migrationsmap.net

Out Migration



Migration Model Calibration

- Can separate terms in migration equation and calibrate separately
- The migration potential (push-pull factor) captures the preference of Malians for different destinations
- UN migrant stock data provides a preference measure for international migration. Data available for 1990, 2000 and 2010

	Frac. of Dest Pop	fraction to destination	
Cote d'Ivoire	0.021	0.436	
Nigeria	0.001	0.128	
Rest of World	0.000	0.101	
Burkina Faso	0.004	0.075	
Ghana	0.003	0.070	
Niger	0.004	0.066	
Gabon	0.027	0.042	
Senegal	0.002	0.029	
Mauritania	0.006	0.020	
Gambia, The	0.009	0.015	
Guinea	0.001	0.011	
Togo	0.000	0.002	
Liberia	0.000	0.002	
Benin	0.000	0.001	
Sierra Leone	0.000	0.001	
USA	0.000	0.001	
Guinea-Bissau	0.000	0.000	
Total			1.000

Migration Model Calibration

- A variety of causal variables were selected for analysis
- Variables were selected to represent key features related to measures of human security
- Data taken from World Bank: World Development Indicators

Variable	Causal argument	Notes/Recommendations
Ag value added	No causal argument. This variable is not used in the literature	Idea is to reflect dependency on agriculture but there are other variables that better capture this. Delete this.
Cereal yield	Food insecurity, lower agricultural yields can lead people to migrate	Food production & cereal yield seem designed to represent the same causal argument. I would recommend using one but not both.
GDP	People may migrate to wealthier countries in search of opportunity; people may be more likely than otherwise to choose to migrate to places which they perceive to offer prospects for a better life	This should be GDPPC.
Sanitation	Contaminated water may force people to migrate	Delete this in first round. Rarely used in literature
Water source	Decreased availability of critical resources may encourage people to migrate	
Mortality	Where environmental degradation exacerbates morbidity and mortality, and reduces incomes, people may migrate	
Refugees		Endogeneity issues. Delete this for this first round.
Distance	People will migrate to countries that are closer to them	
Colonial heritage (COW)	People are likely to travel countries that share cultural/linguistics ties	

Migration Model Calibration

Quantity of Malians within a Country	
Distance	2.292
	(0.331)***
French Language	2.253
	(0.613)***
GDP Per Capita (US$)	0.000
	(0.000)***
# of Battle Deaths	0.000
	(0.000)
Access to Sanitation (% Population)	0.027
	(0.531)***
Number of Observations	437
Chi-Square	112.37***

Statistical significance of coefficients represented as follows: *** p<0.01, ** p<0.05, * p<0.1

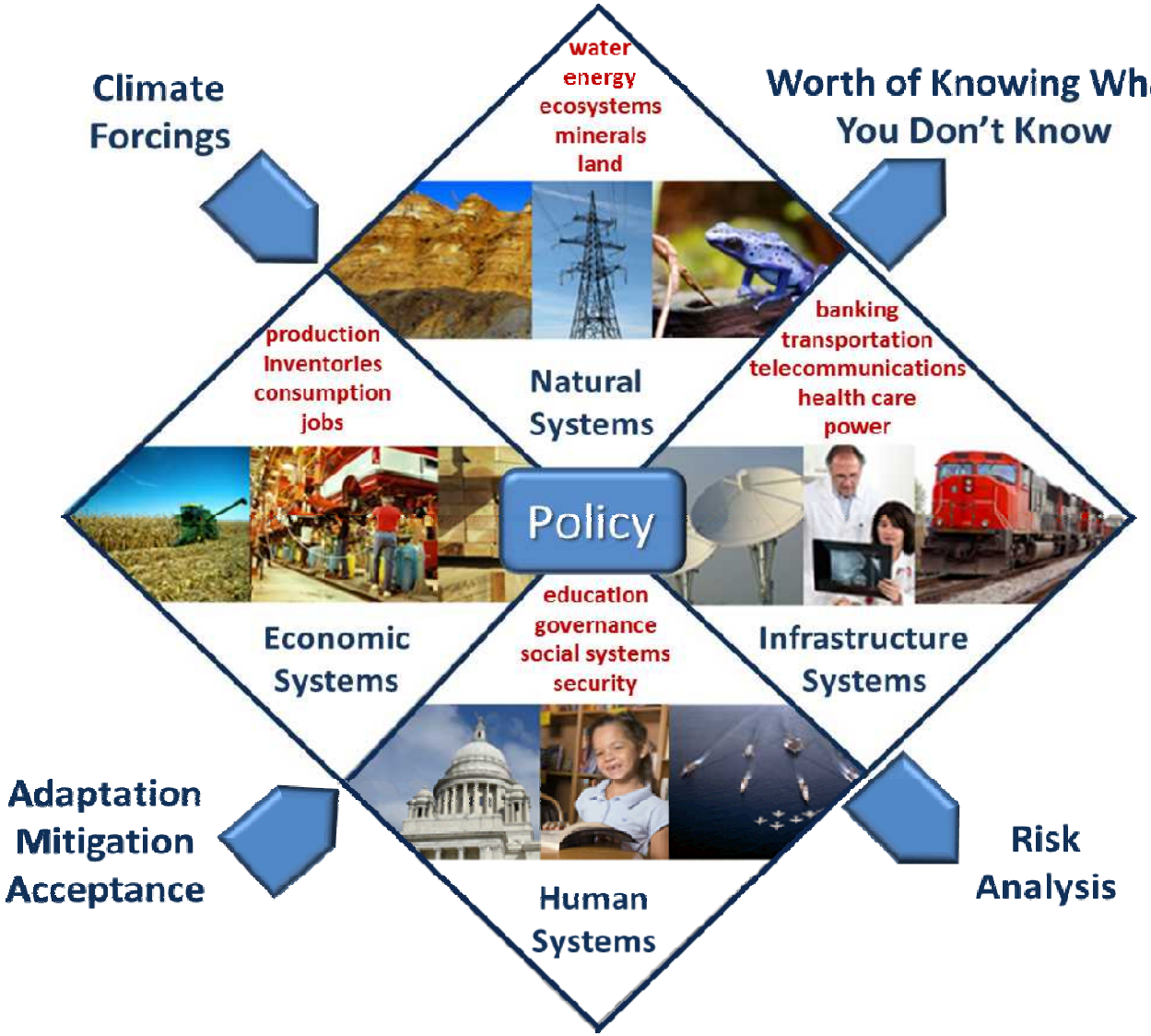
- Due to the distribution of the dependent variable, an ordinal logit is appropriate
- High skewness, high degree of variance on the dependent variable
- Ordinal measure helps address these methodological problems

Dependent Variable	Frequency	Percent Observations
No Malians	289	62.15%
499 or less Malians	114	24.52%
500 or more Malians	62	13.33%

Migration Model Calibration

- Bordering countries:
  - 72% less likely to have no Malians
  - 4% less likely to have to have 499 Malians or less
  - 75% more likely to have more than 500 Malians
- French speaking countries:
  - 50% less likely to have no Malians
  - 29% more likely to have to have 499 Malians or less
  - 21% more likely to have more than 500 Malians
- Wealthy countries: High per capita GDP
  - Wealthiest countries are 51% less likely to have no Malians
  - 12% more likely to have 499 Malians or less
  - 39% more likely to have more than 500 Malians
- Countries with good access to sanitation
  - 50% less likely to have no Malians
  - 33% more likely to have 499 Malians or less
  - 18% more likely to have more than 500 Malians

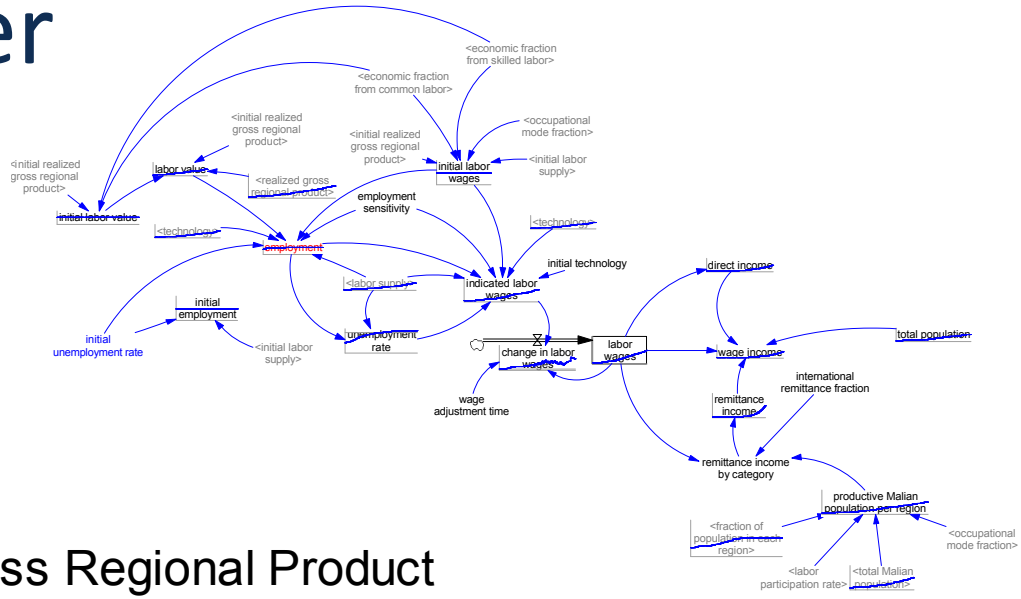
Modeling Spillover



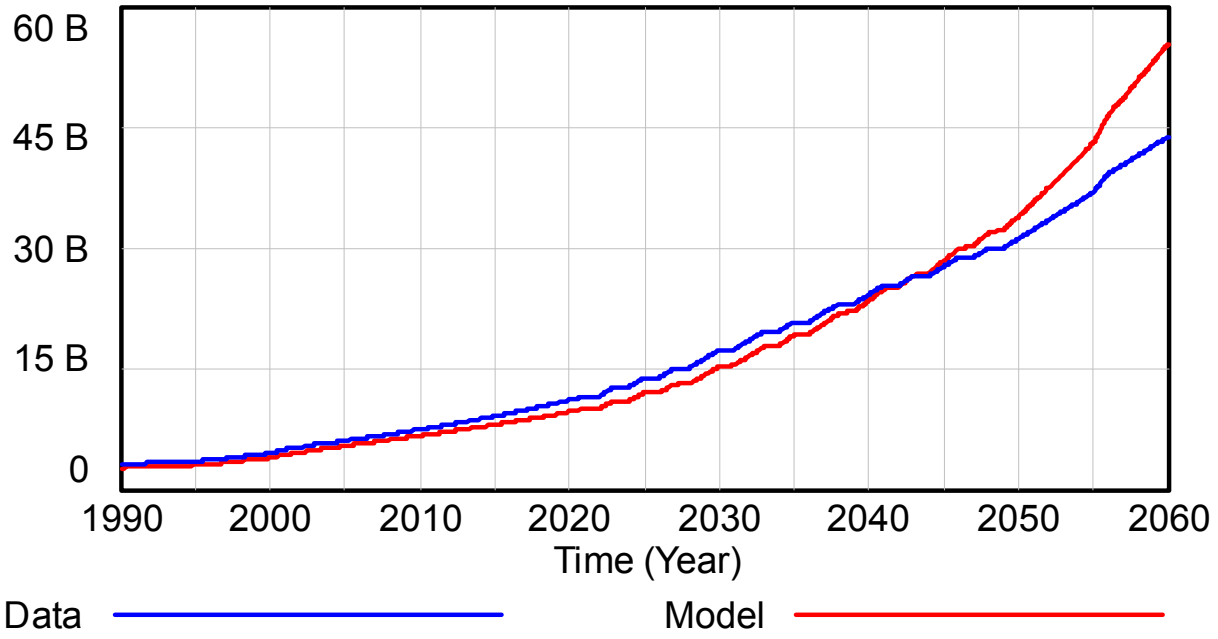
- Both informs and is informed by the migration model
- Integrates interactions between four capital stocks:
  - Human,
  - Economic,
  - Natural resource, and
  - Built.

Modeling Spillover

Model Sectors
- Economic growth
- Labor and wages
- Resource availability
- Food and water availability
- Disease mortality
- Decision-making

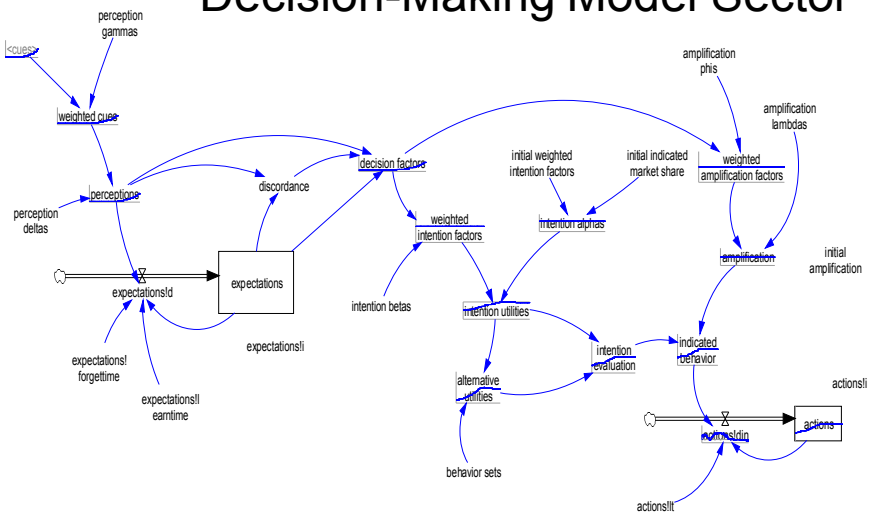


Gross Regional Product

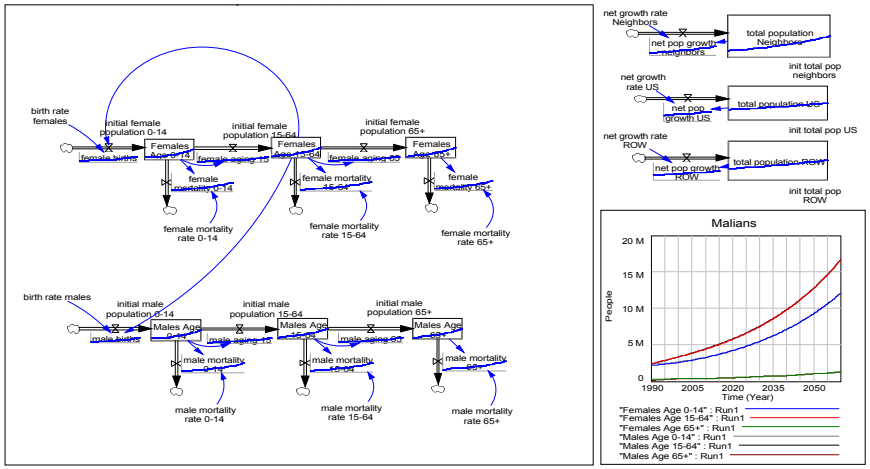


Modeling Spillover

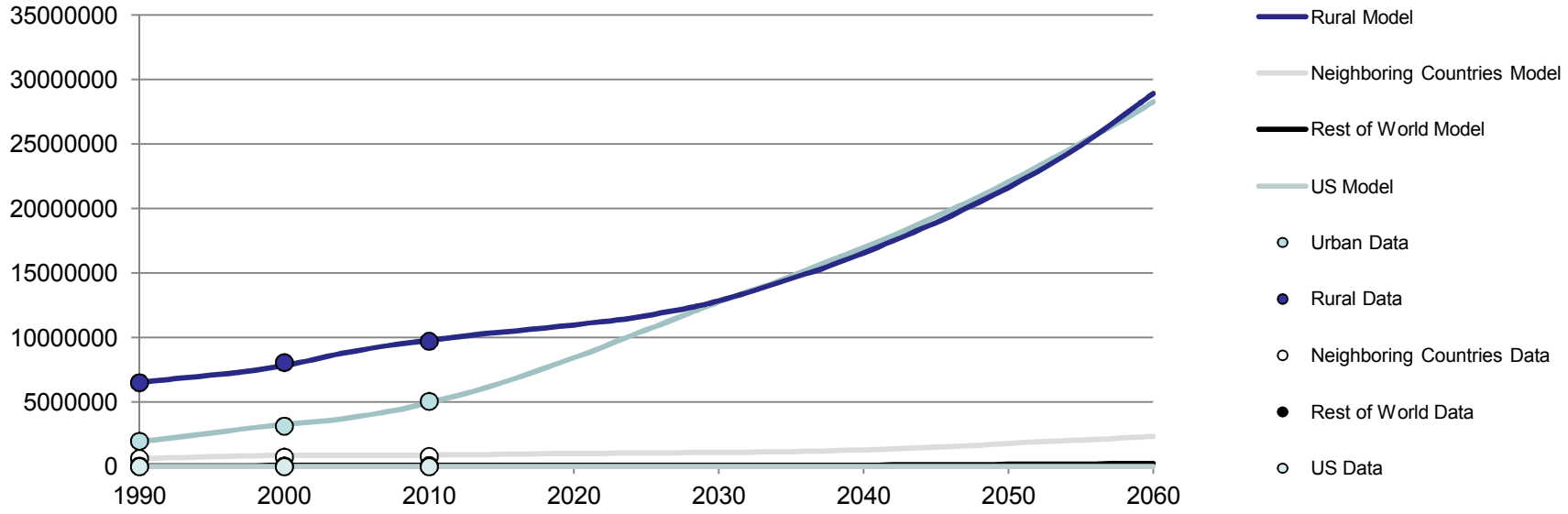
Decision-Making Model Sector



Population Model Sector



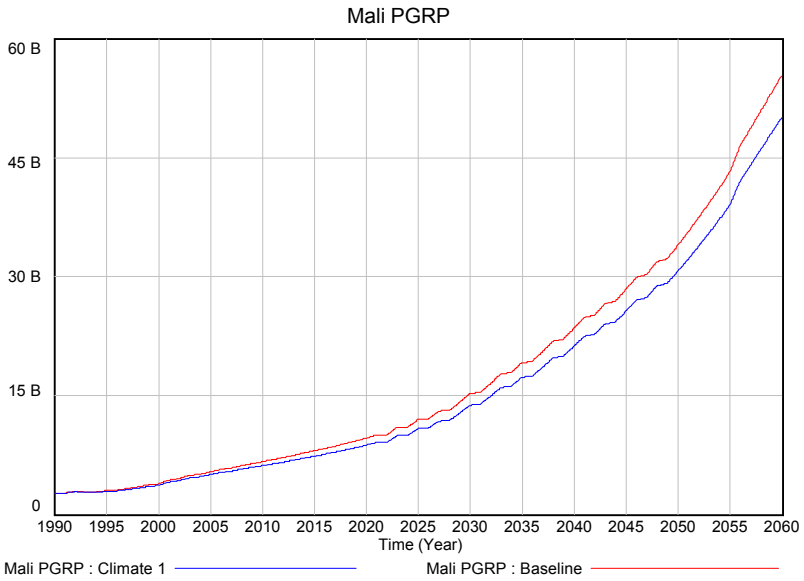
Malian Population by Region

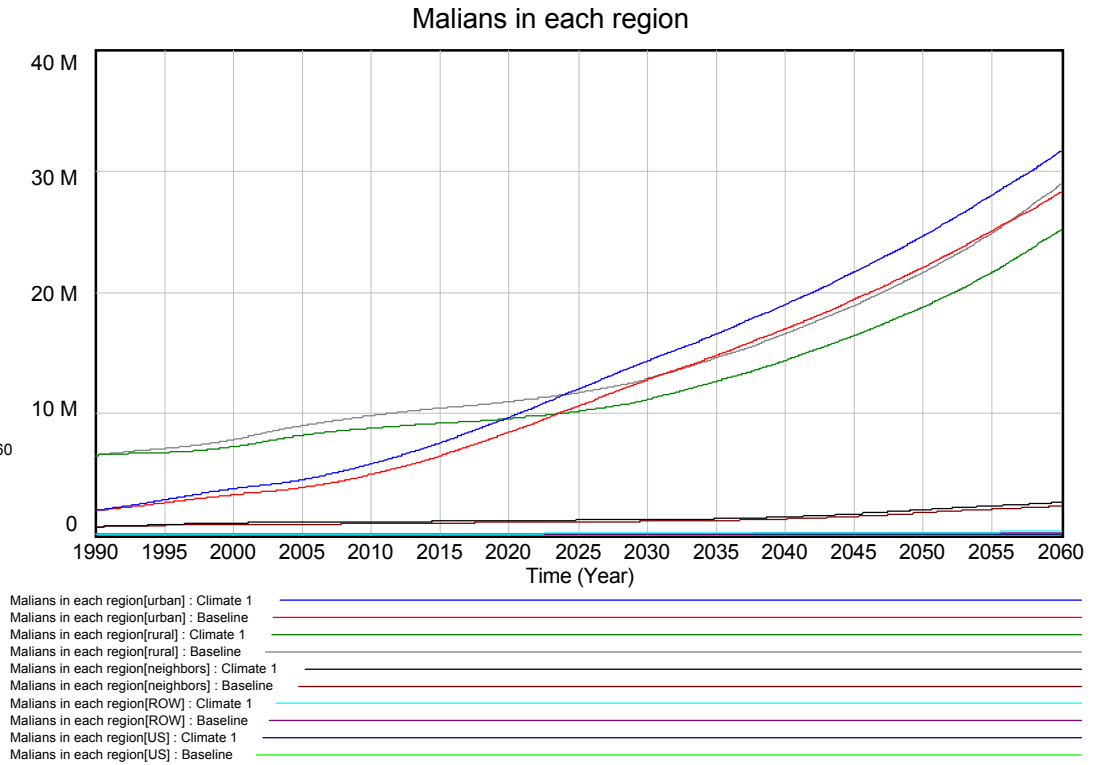


Modeling Spillover

Climate scenario: higher temperature and lower precipitation

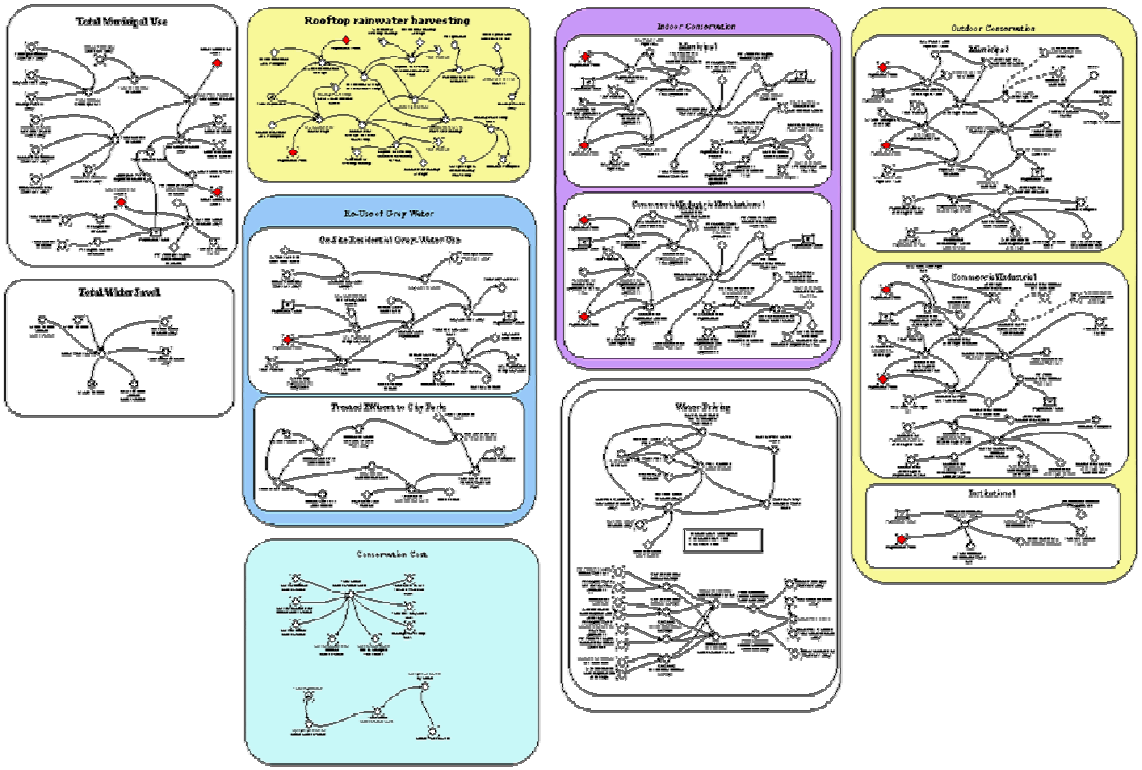
- GDP of Mali drops
- Malians migrate away from rural areas, toward urban regions, and to a smaller extent to other countries

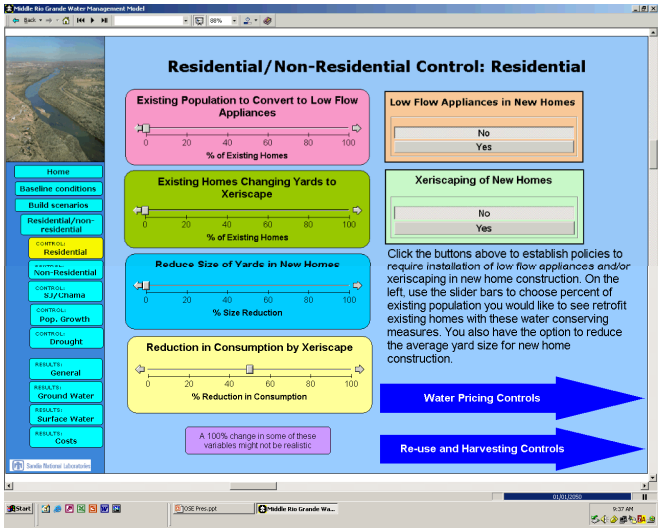




Summary

- Focus is on climate induced domino effect: “Spillover Effect”
- Goal is to develop tool to assist in understanding and managing the Spillover Effect
- Developing model of human migration with form analogous to Fick’s First Law of Diffusion that integrates ideas of:
  - Exposed population
  - Adaptive capacity, and
  - Migration potential (push-pull)
- Agent based model set within broader system dynamics model of the environment
- Mali has been adopted for initial case study





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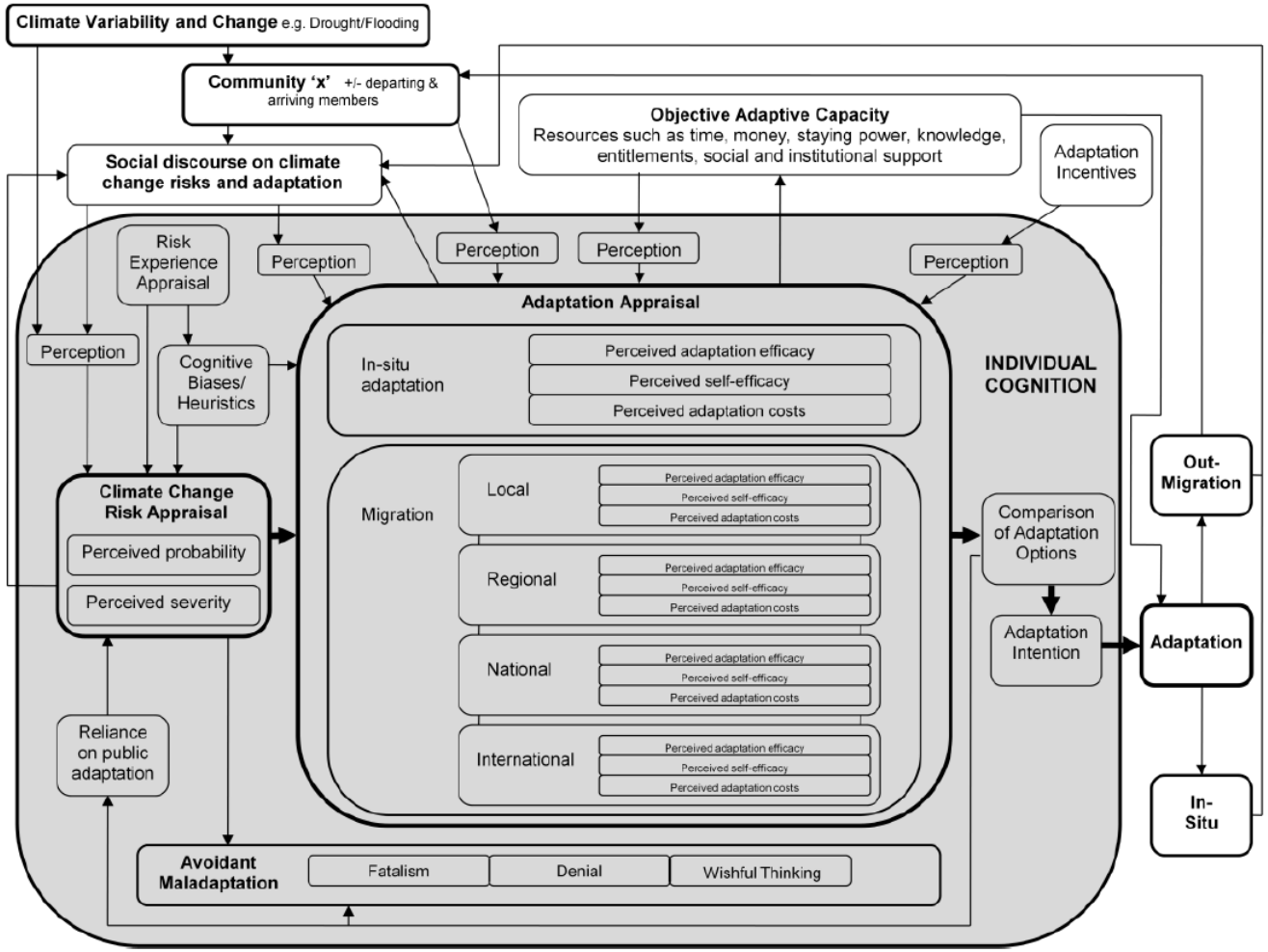
Modeling Human Migration

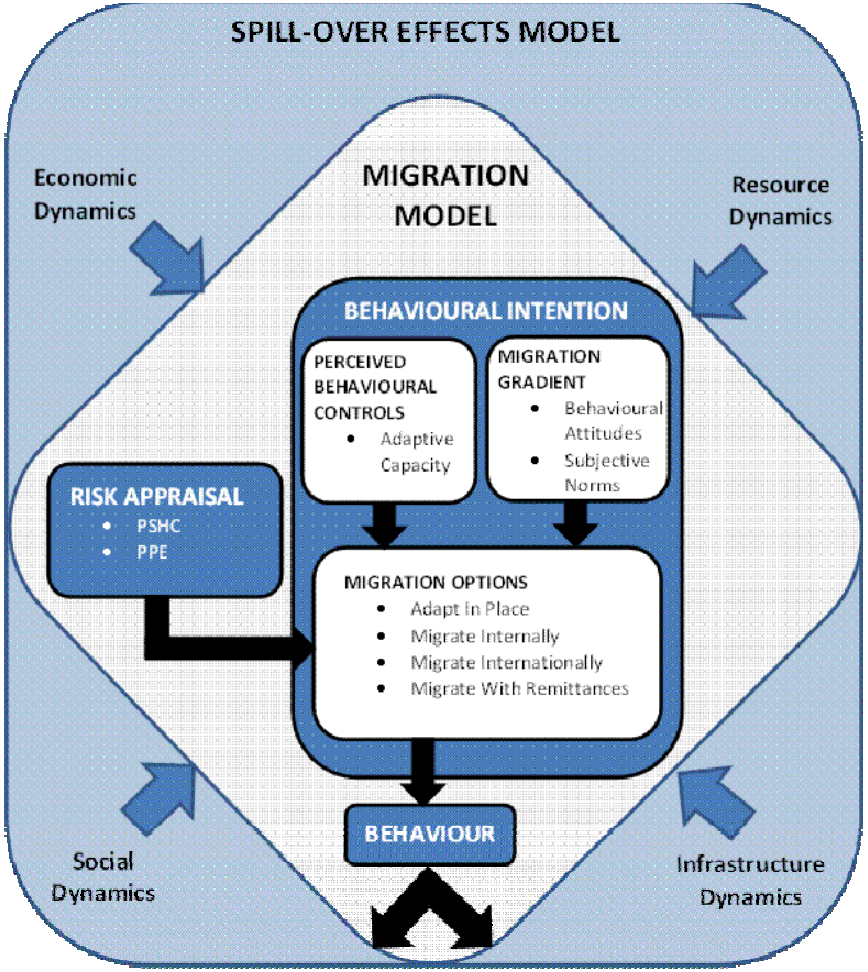


Smith (2012)

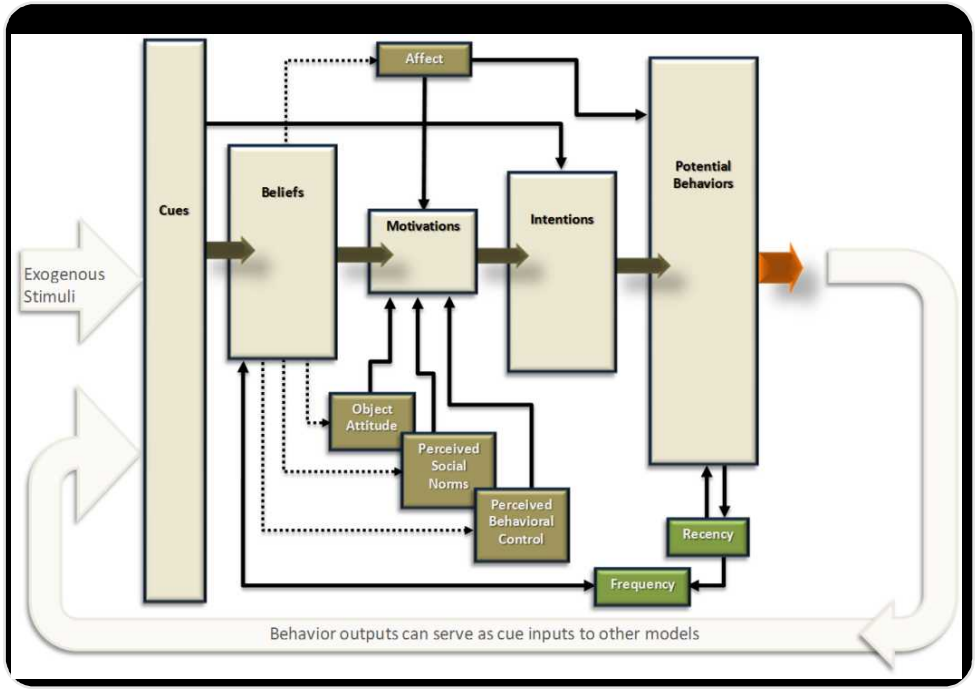
- Operationalize migration model
  - Agent-based framework
  - Protection Motivation Theory
  - Theory of Planned Behavior

Modeling Human Migration

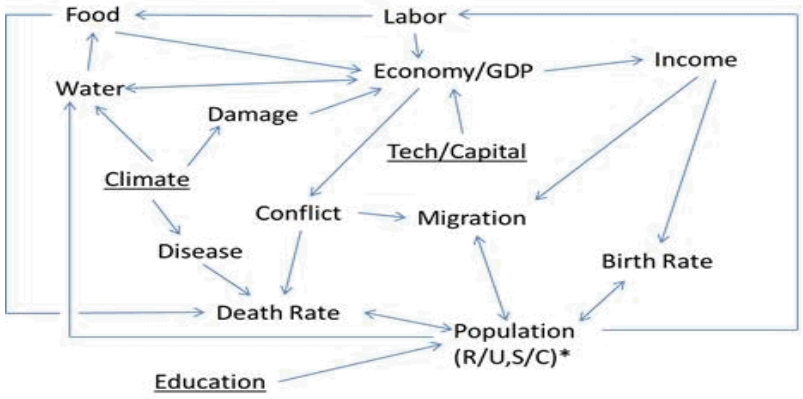
- Theory of Planned Behavior
  - Perceived Behavioral Controls (Adaptive Capacity)
  - Behavioral Attitudes (Migration Potential)
  - Subjective Norms (Migration Potential)
- Protection Motivation Theory (risk appraisal)
  - Perceived probability of exposure
  - Perceived severity of harmful consequences



Modeling Spillover: Mali



- Qualitative Choice analysis of migration and violence.
  - New methods utilize statistical estimates from unrelated (Longitudinal and panel) sparse date sets
  - Multi-region methodology is generalizable to other national-security concerns in other geographical/geopolitical areas.
  - SNL previously tested human response methods for SE Asia, Nigeria, Venezuela, Russia, Turkey.



Modeling Spillover: Mali

- Have completed data-set and parameterization for Mali, Neighboring countries, U.S. and Rest-of-World.
- Climate (extreme event, temperature. precipitation) impacts, demographic and economic dynamics, with uncertainty quantification, based on latest World Bank, United Nations, and Intergovernmental Panel on Climate Change data.