AGENT-BASED MODELLING FOR RETHINKING THE SOCIOECONOMIC DETERMINANTS OF CHILD HEALTH IN SUB-SAHARAN AFRICA

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ABSTRACT

Socioeconomic factors play distal roles in shaping populations' health. In sub-Saharan Africa, these structural health determinants are strongly associated with intermediate determinants of under-5 mortality such as lifestyle factors, health seeking behaviour, or exposure to a health threat. The aim of the study was to use simulation tools for rethinking the dynamics between socioeconomic factors, preventive health measures, and child health. An agent-based model was developed, consisting of rules and equations based on data from four Demographic and Health Surveys conducted in sub-Saharan countries. The model, visualizing the impact of different factors and complex effects, enhanced the understanding and debate on causal pathways of socioeconomic inequalities in under-5 mortality.

Keywords: Socioeconomic, child health, agent-based modelling, population surveys

1. INTRODUCTION

The global under-5 mortality rate has dropped from 90 deaths per 1,000 live births in 1990 to 46 in 2013. The highest rates are in sub-Saharan Africa, with an under-5 mortality rate of 92 deaths per 1,000 live births in 2012. The leading causes of death among children under-5 include pneumonia, preterm birth complications, intrapartum-related complications, diarrhoea and malaria (UN Inter-agency Group for Child Mortality Estimation 2014). Even if under-5 mortality has declined in most sub-Saharan African countries, substantial inequalities exist between population sub-groups within countries (Boco 2010).

The emergence and evolution of socioeconomic inequalities in health involves multiple factors interacting with each other at different levels (individual, household and community). Regression models (such as generalized linear models and decomposition techniques) provided interesting insights on the contribution of different determinants to health and health inequality (Van Malderen C. et al. 2013). However, models incorporating complex and indirect health effects are needed to better understand causal pathways that produce health inequality over time. Simulation models, offering simplified representations of a certain real-life system (Galea et al. 2010; Kaplan et al. 2011; Lempert 2002), have the potential to integrate the growing knowledge about multilevel causes of health and their patterns of feedback and interaction. By mimicking the possible mechanisms responsible for the generation and maintenance of health inequalities, simulation models can also be used to inform how specific policy interventions could influence the health of populations (Auchincloss et al. 2011).

By using simulation modelling, we show a new approach to study socioeconomic determination of health with applying a complexity lens. We show how an agent-based simulation model based on population survey data can help visualizing and understanding the complex processes leading to health and health inequality. The model explores the following questions:

- How to imagine a dynamic population with cross-sectional data?
- Which socioeconomic determinant influences urban versus rural health inequalities the most?
- Why a same shock (or policy change) may have a different health impact depending on the respective country-context?
- How the degree of collectivism could influence a change in socioeconomic determinants?
- What if the association between education and use of preventive health measures was influenced by the level of education in the population?
- What would be the impact of a feedback loop of ill health on the distribution of future socioeconomic determinants?

2. METHODS

2.1. Conceptual framework

Socioeconomic determinants are described as the distal determinants of child mortality in the Mosley and Chen conceptual framework (Mosley and Chen 2003). In their framework, the authors distinguish the community level variables (ecological setting, political economy and health system), the household level variables (income and wealth) and the individual variables (parents' education, time, health, traditions/norms/attitudes). For this simulation exercise and based on available data, the following variables were retained: mother's education, residence (urban or rural), housing, transport means, age of the child and use of preventive health interventions. These determinants are linked together (Figure 1).

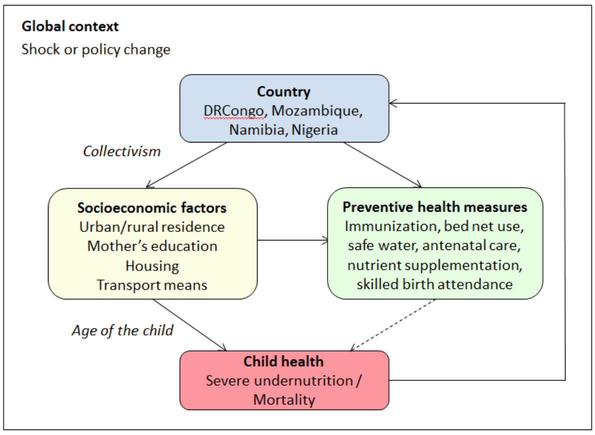


Figure 1: Conceptual framework of studied determinants and under-5 mortality (inspired by (Mosley and Chen 2003)

Dotted arrow: the relationship was not modelled because the cross-sectional data did not allow a reliable assessment of the impact of prevention score on child health.

2.2. Data

Data from Demographic and Health Surveys (DHS) were used. Four sub-Saharan African countries with a recent standard DHS were included: Democratic Republic of the Congo 2013, Mozambique 2011, Namibia 2013, and Nigeria 2013, representing Central, Eastern, Southern and Western Africa, respectively. The analysis was restricted to children under 5 years of age. Details on survey sampling, data collection and data processing can be found in the country reports, available from the Measure DHS website (Measure DHS 2015).

2.2.1. Child age and health

Age of children in months and under-5 (0-59 months) death were obtained from the birth history of interviewed females aged 15 to 49 years old. Weight of children born five years prior to the interview was measured during the survey and weight-for-age standard deviations (according to the World Health Organization 2006 Child Growth Standard) were used to assess undernutrition. Severe undernutrition was defined as weight-for-age less than -3 standard deviations. The health outcome (ill health) is a combination of severe undernutrition and mortality. The idea of combining these two outcomes was proposed by (Mosley and Chen 2003). The combination of the two indicators of ill health allowed a more robust assessment of the regression coefficients avoiding two common problems in regression analysis: the weak number of cases when studying mortality alone, and missing values when studying malnutrition alone.

2.2.2. Preventive health measures

Seven indicators of preventive health measures were gathered into a co-coverage indicator (Barros and Victora 2013): skilled antenatal care attendance (at least one visit with a doctor, midwife or nurse); skilled birth attendance (delivery assisted by a doctor, midwife or nurse); bednet use (whether children under-5 in the household slept under a bednet the night prior to the interview), vitamin A supplementation, BCG (tuberculosis) and DPT3 (diphtheria-tetanus-pertussis) immunization and improved drinking water. A high prevention score was defined as the use of at least four preventive health interventions reported by the mother.

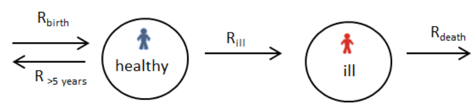
2.2.3. Socioeconomic factors

Four socioeconomic factors were selected according to their reported association with severe undernutrition, mortality and preventive measures in children under 5 (Coleman et al. 2011; Van de Poel et al. 2007; Van de Poel et al. 2009; Van Malderen C. et al. 2013) and the availability of data: urban or rural residence, mother's education (primary education completed or not), quality housing (quality floor, roof and wall + improved toilet facility), and transport means (having a car or a motorbike).

2.3. Description of the model

Child

Health status	The child is healthy (0) or ill (1)
Age	Age of the child in months
Urban	The child lives in a urban residence or not
Education	The mother has a primary education level, or none
Housing	The child lives in a quality house or not
Transport	The child lives in a household having a moto or a car



Parameter	Description
R_{birth}	Births (alive) in the population each month
$R_{>5\ years}$	Children older than 5 years old leave the population
R_{ill}	P(get ill) = f(urban, education, housing, transport)
R_{death}	Ill children leave the population

Figure 2: Model overview: agent, variables and health pathways

The population consists of children 0 to 59 months old characterized by the following variables: health status, age, urban residence, mother's primary education, quality housing, and transport means (Figure 2). DHS datasets were transferred to RGui (R version

3.1.1., The R foundation for Statistical Computing) for analysis. The distribution of children's socioeconomic data -urban residence, education, housing and transport- were transferred into Netlogo 5.2-RC3 using the R package "RNetLogo".

The time unit is one month. Each month, 1000 children are born and enter the population. Each created child receives the socioeconomic attributes of a child randomly selected from the survey data. Children may transit through two different states: healthy or ill health (severe undernutrition or death). Each month, new children are born, grow up, and have a R_{ill} probability to get ill. Children leave the population when they are ill or when they reach 60 months of age.

2.4. Regression equations

Equations for calculating probabilities of having a high prevention score and of child ill health (R_{ill}) given the observed values of the socioeconomic factors were obtained with logistic regression. The general formula was:

$$\text{Logit}(p) = \alpha + \beta_1 \text{ urban} + \beta_2 \text{ education} + \beta_3 \text{ housing} + \beta_4 \text{ transport}$$

In each country, the parameters α, β_1, β_2, β_3 and β_4 were assessed for three outcomes:

- having a high prevention score
- becoming ill if the child is less than 12 months old
- becoming ill if the child is 12-59 months old.

Regression coefficients were then transferred into Netlogo for the simulation. For a given child, the probability of having a high prevention score or becoming ill was derived from the logit(p) obtained with the aforementioned regression equations.

2.5. Outcomes

Two outcomes are compared between urban and rural areas:

- Proportion of high prevention score
- Incidence of ill health

2.6. Scenarios

After children are created according to the DHS values, a proportion of children either loses (shock: event of an environmental or man-made origin that impacts on socioeconomic determinants) or gain (policy change) one or several socioeconomic attributes.

2.7. Additional (optional) if-then rules

Several rules were added to the model to account for more complexity (Table 1). First, the possible effect of a country's degree of collectivism (collectivism, contrary to individualism, "pertains to societies in which people from birth onwards are integrated into strong, cohesive in-groups, which throughout people's lifetime continue to protect them in exchange for unquestioning loyalty" (Allik and Realo 2004)) was modelled. Second, the association between education and preventive health measures uptake (the higher the level of education in a population, the higher the association between health messages and preventive health measures uptake) was tested. This assumption integrates the idea that "campaign strategies may only be successful to the degree that they are backed by community education" (Saunders and Goddard 2015). Third, a feedback loop modelling the effect of child health on future socioeconomic determinants was introduced. The historical association between declines in child mortality, rising education and economic growth was modelled in (Azarnert 2005).

Table 1: Additional if/then rules

	Rule
High collectivism	If a child's education, housing, or transport is 0, then it becomes the average of his closest neighbours with a given probability. Rural and urban areas are separated in the simulation space.
Variable slope	The association between education and preventive health measures uptake is proportional to the level of education in the population; the slope, recalculated each month, is increased by the average education in a given subgroup.
Feedback loop	A monthly decrease in ill health is applied. Education, housing and transport in new children are increased by either the ratio or the difference between the baseline mortality and the actualized month's mortality level.

3. RESULTS

The six research questions listed in the introduction were explored using the basic simulation model and additional if-then rules. In this simulation we made the assumption that regression equations remain unchanged month after month. Results should not be interpreted as predictions. Units were expressly removed from plots so the reader can focus on behavior over time.

3.1. How to imagine a dynamic population with cross-sectional data?

3.1.1. Regression coefficients

Table 2: Regression coefficients from the multivariate regression models estimating the effect of socioeconomic determinants on a high prevention score and ill health, DHS 2011-2013

	Prevention	Ill health (<12 months)	Ill health (12-59 months)
DRCongo			
intercept	-1.14	-1.72	-1.05
urban	1.05	-0.37	-0.17
education	0.36	0.05	-0.26
housing	1.07	-0.71	-0.22
transport	0.13	0.34	-0.20
Mozambique			
intercept	-0.98	-2.01	-1.88
urban	1.30	0.15	-0.10
education	0.83	-0.92	-0.32
housing	0.95	-0.26	-0.10
transport	0.34	-0.36	-0.31
Namibia			
intercept	0.37	-1.36	-1.50
urban	0.56	0.00	0.20
education	0.70	-0.59	-0.11
housing	0.26	0.47	-0.58
transport	0.09	-0.32	-0.63
Nigeria			
intercept	-3.00	-1.31	-0.83
urban	0.93	-0.09	-0.14
education	2.10	-0.50	-0.75
housing	0.94	-0.07	-0.27
transport	0.03	-0.12	-0.06

In the four countries, all socioeconomic determinants were associated with a high prevention score (Table 2). In infants less than 12 months old, transport means, urban residence and quality housing were associated with higher odds of ill health in some countries. In children 12-59 months old, socioeconomic determinants were associated with lower odds of ill health, with the exception of urban residence in Namibia.

3.1.2. Simulated versus observed values

Table 3: Comparison between observed (DHS) and simulated values of socioeconomic determinants, preventive health measures uptake and ill health.

	DRCongo (N = 18446)		Mozambique (N = 10609)		Namibia (N = 4896)		Nigeria (N = 30959)	
	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.
Urban	29	28-38	30	29-36	45	44-46	33	32-40
Education	44	44-48	19	20-31	75	76-82	47	48-59
Housing	7	8-12	9	9-13	31	27-31	28	28-35
Transport	6	6-7	9	9-13	20	20-25	46	46-51
Prevention*	31	23-35	47	27-43	77	47-67	28	17-30
Ill health	22	14-16	11	10-12	16	14-18	20	15-18

Obs.=observed value from DHS data; Sim. = minimum and maximum value obtained from a 100 months simulation. *For the observed values, DRCongo: N = 9995, Mozambique: N=6303, Namibia: N=2973, Nigeria: N=16871

At the first step of the simulation (setup), the distribution of socioeconomic attributes in the simulated population was similar to the distribution observed in the DHS data (Table 2).

After running the simulation, some socioeconomic determinants deviated from their initial values, because of a higher mortality in several socioeconomic sub-groups. For instance, in DRCongo, the proportion of children in urban areas increased from 28 to 38 because children in urban areas had a lower death probability (see regression equations in Table 2). Accordingly, as the socioeconomic determinants associated with better outcomes underwent a "natural selection", preventive health measures uptake and ill health also improved (simulated prevention scores were higher and simulated ill health values were lower) compared to observed values.

3.2. Which socioeconomic determinant influences urban-rural inequality in use of preventive measures and ill health outcome the most?

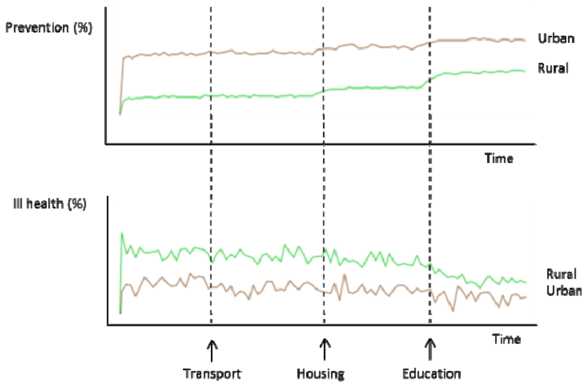


Figure 3: Impact of increased proportions of transport, housing and education on the prevention score and ill health by type of residence, Nigeria

The country with the highest absolute urban-rural inequality in ill health, Nigeria, was selected to illustrate how changing the proportion of socioeconomic determinants in the virtual population was expected to impact prevention and ill health outcomes.

Transport, housing and education increased by 25% in new children entering the model. Education had the strongest impact on both preventive health measures uptake and ill health. Indeed, education was positively associated with a high prevention score and negatively associated with ill health in both age groups (Table 2).

3.3. Why a same shock (or policy change) may have a different health impact depending on the respective country-context?

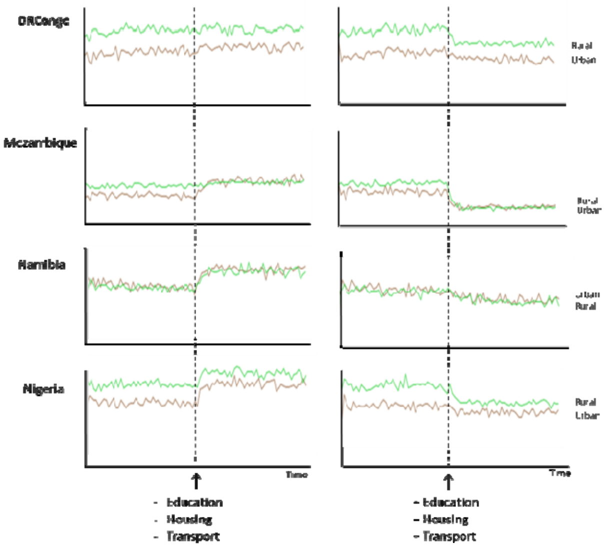


Figure 4: Impact of a shock and policy change targeting the three socioeconomic determinants on child ill health (%) in the four countries

In the four countries, after 45 simulation months, a shock lowering education, housing and transport by 25% in newborn children was applied (Figure 4, left). This simulation shows that the impact of a shock with a similar socioeconomic impact may differ according to the country-context.

In DRCongo, a shock did not result in a marked increase in ill health. Looking at the changes in the socioeconomic determinants, education initially at 44% showed a large decrease, whereas housing and transport that were low at baseline (8-12 and 6-7, respectively) remained low. Moreover, in this country, education was not negatively associated with ill health in infants less than 12 months old (Table 2).

In Mozambique, the shock resulted in an increase in ill health in urban areas. Indeed, urban residence is positively associated with ill health in infants less than 12 months old, and the effect of the induced shock could not be counteracted by the socioeconomic determinants (Table 2).

In Nigeria, where all socioeconomic determinants were associated with less ill health, the shock resulted in an increase in ill health for all children. A positive intervention that increases education, housing and transport by 25% (Figure 4, on the right) resulted in larger decreases of ill health in countries were the socioeconomic determinants were initially low, such as in DRCongo, Mozambique and rural Nigeria (Table 1).

3.4. How the degree of collectivism could influence a change in the socioeconomic determinants?

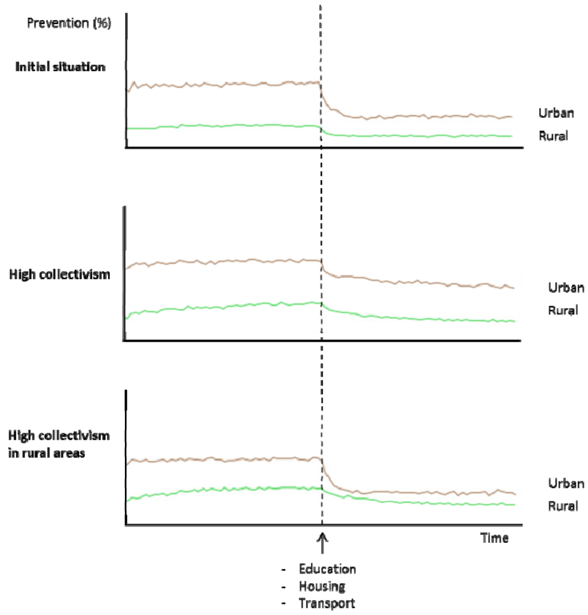


Figure 5: Impact of a shock affecting the three socioeconomic determinants on the prevention score and the role of collectivism, Nigeria

In this simulation, rural and urban areas were separated in the simulation space and children without education, housing or transport had a 50% probability to get these resources from their neighbours (Figure 5).

In the initial situation, the simulated shock (25% reduction in the three socioeconomic determinants) resulted in a large decrease in preventive measures use. In case of collectivism, this decrease was softened. When the collectivism rule was applied only in children from rural areas, the urban-rural inequality tended to be lower.

3.5. What if the association between education and use of preventive health measures was influenced by the mean of education in the population?

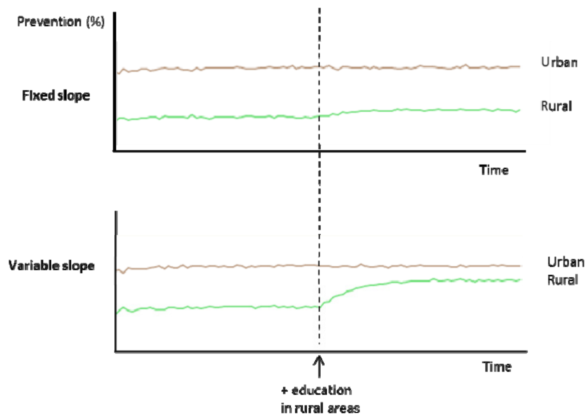


Figure 6: How changing the association (slope) between education and preventive measures use could improve the coverage of preventive health measures in rural areas, Mozambique

In the samples used, Mozambique showed the lowest coverage in education. In the first simulation (fixed slope obtained from the regression analysis), after 45 months education increased by 5% each month in rural areas (Figure 6). In the second simulation (variable slope), education also increased by 5% each month in rural areas. In addition, in rural areas the slope of education in the equation determining odds of having a high prevention score was proportionate to the level of education of rural areas. In urban areas no additional rule was applied.

The simulation illustrates that increasing education (literacy) and its association with increased uptake of preventive health measures (e.g., through information, education and communication activities) could result in a greater improvement in preventive health measures coverage than increasing education alone.

3.6. What would be the impact of a feedback loop of ill health on future socioeconomic determinants?

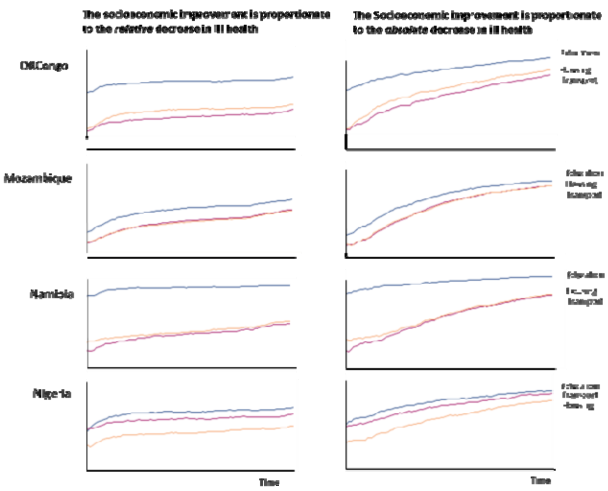


Figure 7: How a decrease in mortality could impact the socioeconomic determinants in the four countries

Here, a monthly decrease in ill health (the intercept) was applied and the impact of such a decrease on the socioeconomic determinants was simulated in two different ways. Education, housing and transport in new children were increased by (i) the ratio (Figure 7, left) and (ii) the difference (Figure 7, right) between the baseline mortality and the actualized month's mortality level.

This exercise illustrates that improvement in the socioeconomic determinants could be possible if the overall situation in the country would improve. The assumptions, though totally imaginary (how could this observation be ever tested in real-time?), raise the question on how this improvement could be obtained by a reduction in ill health. The improvement in socioeconomic resources resulted in an improvement in preventive health measures coverage and could have an accelerating effect on improved health outcomes (decreased ill health). Note that the accelerated decline was weak because a weak reduction in ill health (0.15% decline) was modelled.

4. DISCUSSION

The paper aimed at introducing a new approach for rethinking the socioeconomic determination of health and exploring complex features that go beyond the scope of what is usually studied.

4.1. Benefits

4.1.1. Imagine the impact of a change in a socioeconomic determinant on a population health and health inequality

In its most basic form, the model reproduces the patterns obtained from the regression equations assessed on the DHS data. Taking real combination of socioeconomic attributes and applying the regression equations obtained from the same DHS data allows having an idea of the possible impact of a determinant.

Interpreting the coefficient only does not directly inform on how a change in this determinant will affect the health of population and health distribution between urban and rural areas. Indeed, the improvement in outcomes may depend on the initial proportions of socioeconomic determinants. In DRCongo and Mozambique, the gain obtained from an increase in the three socioeconomic determinants was higher than in Namibia where the initial proportion of education was already high.

The effect of improvement in socioeconomic determinants on urban-rural inequalities in preventive health measures uptake and health depends on several elements: the proportion of children in urban and rural areas; the proportion of socioeconomic determinants in each area; the association of urban residence with preventive health measures uptake and health; having a global vision of the phenomenon is hard when considering each element separately. The simulation allowed first visualizing the situation and then trying to understand the observed patterns by looking at the possible effect of each element.

4.1.2. Taking an interaction into account: having a vision of under-five mortality knowing that the effects of socioeconomic determinants may differ according to age of the child

An important added value is to visualize simultaneously the effects of three different equations: prevention score, ill health in children <12 months and ill health in children 12-59 months according to the same socioeconomic determinants. When studying the effect of determinants of one outcome, it remains easy to understand the effect of each determinant included and the possible change in the outcome that could be induced if the determinant was changed. Determinants of child mortality may differ according to age of the child and studies usually focus either on the determinants of infant (<12 months) mortality (Drevenstedt et al. 2008; Hosseinpoor et al. 2006; Van de Poel et al. 2009) or child (0-59 months) (Ayotunde et al. 2009; Garenne and Gakusi 2006; Houweling et al.

2005) mortality. Distinguish the effects in both sub-groups keeping under-5 ill health as an outcome could be possible in this simulation.
In countries where some determinants were positively associated with ill health in one age group but negatively associated with ill health in the other age group, the simulation allowed visualizing what would be the total effect on the overall child health.

4.1.3. Visualize the production of two outcomes simultaneously

In this simulation, two outcomes were visualized simultaneously: the prevention score and ill health, according to the same socioeconomic determinants. Though the direct relation between preventive measures and child health could not be modelled, studying both simultaneously allowed observing how improvements in socioeconomic determinants directly improved either preventive health measures coverage or child health. The latter were usually less marked, and reasons are specific for each situation. Either association (coefficients) with the prevention score were higher than with ill health, or determinants were positively associated with ill health in one age group and negatively associated with ill health in the other age group (e.g., housing in Namibia).

4.1.4. Imagine the role of complex effects

Complex effects such as the role of social capital (Allik and Realo 2004) or the impact of ill health on socioeconomic resources (Azarnert 2005) are assumed but hardly quantifiable. In the simulation such complex effect were yet modelled. While the formulation of rules is arbitrary and does not pretend to explain what really happens, it attempts to imagine how complex and still unknown processes shape population health, and increase awareness of complex effects.

4.2. Limitations

Limitations are all the unavoidable analytical and interpretation errors that could occur at each step of the study, e.g.: data collection (including biases linked to interviews), use of preventive health measures and ill health scores, regression coefficient estimations, transformation of logit(p) into probabilities, choices of the rules. The only validation possible was comparing the simulated proportions of the selected variables with the DHS proportions. Moreover, the development of a dynamic vision (process-based) from cross-sectional data was a major challenge of the study. The aforementioned limitations do not allow the model to perform predictions.

4.3. Perspectives

Simulation modelling involves a lengthy process of combining data analysis, expert opinions, variables and equations selection and rules formulation, and exploring simulation outputs (Figure 8). Learning about the subject (here, socioeconomic determinants of child health) occurs at each step. The questions explored here, such as the role of social capital, interactions between education and preventive health measures and applying feedback loops, will stimulate new investigations. The discussion with experts initiated in the development of this initial model will be continued; simulation outputs will be confronted and variables, equations and rules could be further adapted.

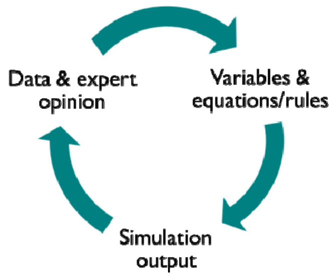


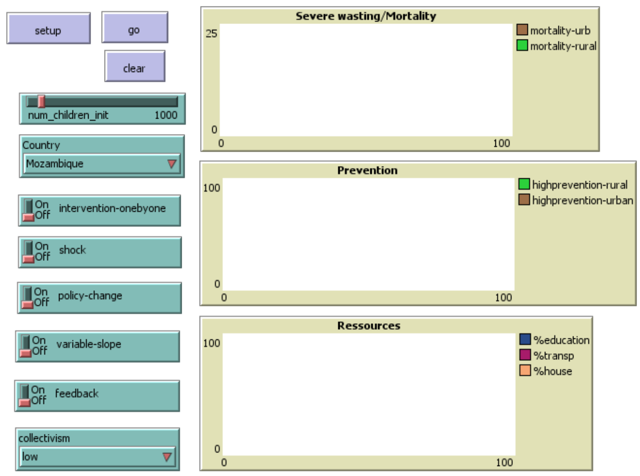
Figure 8: Process of learning about the mechanism of socioeconomic health determinants in children through simulation modelling

ACKNOWLEDGMENTS

We thank Cesar Victora and Aluisio Barros (International Center for Equity in Health, Pelotas, Brazil) for their contribution in the development of the conceptual framework and their advice in the development of the simulation model.

APPENDIX

1. OVERVIEW OF THE NETLOGO INTERFACE



2. R CODE (RNETLOGO): EXAMPLES

```
# a vector with total number of children
in each country
num<-c(18446,11377,30959, 4896, 10609 )

# Initialization in Netlogo
NLCommand("clear")

# put data into Netlogo :
# the « num » vector
```

```
NLDfToList(num)

# a dataframe with regression
coefficients for the three outcomes
NLDfToList(DRCglm[,2:4])

# the database with the four
socioeconomic variables
NLDfToList(DRCongo)

# specify the country in the Netlogo
chooser
NLCommand("set Country \"DRCongo\"")

# run the setup in Netlogo
NLCommand("setup")

# report the minimum and maximum
percentage of urban for 100 months
urbs <- NLDoReport(100, "go", "%urb")
min(unlist(urbs))
max(unlist(urbs))
```

3. NETLOGO CODE

The full model may be accessed on http://socioeconomicdeterminants.sourceforge.net .

The following lines show some extracts for illustration.

```
;*****************************************
; globals
;*****************************************
globals [
house urb ed transp ; socioeconomic
variables imported from R (Demographic
and Health Surveys) with RNetlogo. These
are list ranging from 0 to the total
number of individuals in the country.
X2 X3 X4 ; lists of regression
coefficients for ill health in children
<12 months old (R2), ill health in
children 12-59 months old (R3) and a high
prevention score (R4), imported from R
num ; a list containing the total number
of individuals for each country, imported
from R
mortality2 ; a list containing mortality
rates for each simulated month
Pfeed ]

;*****************************************
; Children
;*****************************************
breed [children child]
children-own [status age prevention
transport housing education urban]

to setup-children [num_children]
if ticks = 0 [ set mortality2 [  ] ]
set-default-shape children "person"
create-children num_children [ ; the
number of created children is given by
the slider "num_children"
set age random 0
set status 0
set color blue
let number 0
let ncountry 0
if Country = "DRCongo" [set ncountry 0]
if Country = "Ethiopia" [set ncountry 1]
if Country = "Nigeria" [set ncountry 2]
if Country = "Namibia" [set ncountry 3]
if Country = "Mozambique" [set ncountry
4]
set number random item ncountry num ; a
number between 0 and the total number of
individuals in the country is randomly
selected
set transport item number transp ; each
created child receives attributes from
the child randomly selected in the list
(at the position defined by the number
selected in the line above)
set education item number ed
set housing item number house
set urban item number urb]

; optional if-then rules
if intervention-onebyone [
if ticks = 18 [ ask children with
[education = 0] [if random 100 < 25 [set
education 1]]]
    if ticks = 42 [ ask children with
[transport = 0] [if random 100 < 25 [set
transport 1]]]
    if ticks = 66 [ ask children with
[housing = 0] [if random 100 < 25 [set
housing 1]]]]

if shock [ if ticks > 50 [
ask children with [education = 1] [if
random 100 < 25 [set education 0]]
ask children with [transport = 1] [if
random 100 < 25 [set transport 0]]
ask children with [housing = 1] [if
random 100 < 25 [set housing 0]]]]

if policy-change [ if ticks > 50 [
ask children with [education = 0 ] [if
random 100 < 25 [set education 1]]
ask children with [transport = 0] [if
random 100 < 25 [set transport 1]]
ask children with [housing = 0] [if
random 100 < 25 [set housing 1]]]]

if feedback [ if ticks > 1 [
set Pfeed (( item 1 mortality2 - item
(ticks - 1 ) mortality2))
ask children with [education = 0] [if
random 100 < Pfeed [set education 1]]
ask children  with [transport = 0] [if
random 100 < Pfeed [set transport 1]]
ask children with [housing = 0] [if
random 100 < Pfeed [set housing 1]]]]

; separate children from urban and rural
area for the collectivism rule
ask children with [urban = 1] [set xcor
random-float -16 set ycor random-ycor]
ask children with [urban = 0] [set xcor
random-float 16 set ycor random-ycor]
end

;*****************************************
```

```
; children actions (every month)
;*************************************
to old
ask children [ set age age + 1  if age >
59 [die]]
end

to become-wastedordead
let logitdead 0
let Pdead 0
ask children with [status = 0] [
let intercept1 0
let intercept2 0
set intercept1 item 0 x2
set intercept2 item 0 x3
if feedback [set intercept1 intercept1 -
ticks * 0.01]
if feedback [set intercept2 intercept2 -
ticks * 0.01]
ifelse age < 12
[set logitdead intercept1 + (item 1 X2 *
transport) + (item 2 X2  * housing) + (
item 3 X2 * education) + (item 4 X2 *
urban)]
 [set logitdead intercept2  + (item 1 X3
* transport) + ( item 2 X3 * housing) +
(item 3 X3 * education)+ (item 4 X3 *
urban)]
set Pdead (exp (logitdead) )/ ((1 +
exp(logitdead))) * 100
if random 100 < Pdead [set status 1 set
color red]]
end

to compute-prevention
  ask children [
    let logitprevent 0
    let Pprevent 0
    let slope 0
ifelse variable-slope
[   ifelse urban = 1
    [set slope item 3 X4]
    [set slope item 3 X4 + %ed-urban]]
[ set slope item 3 X4]
    set logitprevent  item 0 X4 + (item 1
X4   * transport ) + ( item 2 X4  *
housing ) + ( slope   * education) +
(item 4 X4 * urban)
    set Pprevent exp (logitprevent) / (1
+ exp(logitprevent)) * 100
    ifelse random-float 100 < Pprevent
    [set prevention 1]
    [set prevention 0]]
end

; collectivism if-then rule
to get-transport
  if collectivism = "high"  [
  ask children with [transport = 0 and
urban = 0] [if any? turtles-on neighbors
and random 100 < 50 [set transport mean
[transport] of turtles-on neighbors]]]
end

to get-education
  if collectivism = "high" [
  ask children with [education = 0 and
urban = 0] [if any? turtles-on neighbors
and random 100 < 50 [set education mean
[education] of turtles-on neighbors]]]
end

to get-housing
  if collectivism = "high"  [
  ask children with [housing = 0 and
urban = 0] [if any? turtles-on neighbors
and random 100 < 50 [set housing mean
[housing] of turtles-on neighbors]]]
end

;*****************************************
; setup
;*****************************************
to setup
  setup-children num_children_init
  reset-ticks
end


;*****************************************
; go
;*****************************************
to go
 get-transport
 get-education
 get-housing
 compute-prevention
 become-wastedordead
 set mortality2 lput mortality mortality2
 tick
 old
 setup-children num_children_init
 ask children with [status = 1] [die]
end


;*****************************************
; clear
;*****************************************
to clear
    __clear-all-and-reset-ticks
    set num_children_init 1000

    set collectivism "low"

end
```

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