

Microsimulation microWB Demo model

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Model overview

microWB is a “simple on purpose” demo model showing some key characteristics and uses of microsimulation

- Not a particular society but using “realistic” parameters
- **Population:** Female population from Malawi Demographic and Health Survey DHS (male children added for child mortality only)
- **Linked lives:** mothers’ education has impact on education and mortality of children, the birth order influences migration.
- **Minority:** an “artificially” created minority with “more traditional” demographic behaviors – “typical” relative risks added to most models

Processes

- **Fertility** estimated from DHS
- **First union formation** estimated from DHS
- **Migration**: initial composition from data, migration decisions based on age, education and birth order are made up for demonstrational purposes
- **Education**: three levels, depending on mother's education and other characteristics, parameters as found in literature
- **Mortality**: based on education resp. Mother's education and sex

Model estimates

- **Typical Example:** First union formation
- Proportional hazard regression model
 - Baseline hazard by age group
 - Relative risks by motherhood, education and minority status

Parameter: Age baseline for first union formation

Columns:
AGE_GROUP

| | (min,10) | [10,12.5) | [12.5,15) | [15,17.5) | [17.5,20) | [20,22.5) | [22.5,25) | [25,27.5) | [27.5,30) | [30,32.5) | [32.5,35) | [35,37.5) | [37.5,40) | [40,42.5) | [42.5,45) | [45,47.5) | [47.5,50) | [50,max) |
|--|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|----------|
| | 0.000 | 0.008 | 0.050 | 0.201 | 0.413 | 0.441 | 0.410 | 0.404 | 0.311 | 0.265 | 0.183 | 0.115 | 0.112 | 0.479 | 0.119 | 0.189 | 0.000 | 0.000 |

Parameter: Relative risks for first union formation

Columns:
Relative risks of first union formation

| | First period after first birth | Second period after first birth | After second period after first birth | Primary Education | Secondary Education | Minority studied | Urban |
|--|--------------------------------|---------------------------------|---------------------------------------|-------------------|---------------------|------------------|-------|
| | 1.212 | 0.927 | 0.673 | 0.995 | 0.393 | 1.579 | 0.917 |

Scenarios

- **Base Scenario - Status Quo:** demographic pattern as observed today for younger generation, education transmission calibrated resulting in constant attainments over next generations
- **Education intervention Scenario 1 - overall increase** in odds to graduate from primary and secondary school; relative differences between population groups kept constant
- **Education intervention Scenario 2 – closing gaps:** the gap between minority and rest as well as between urban and rural population is closed completely, the gap by parental education is reduced by half
- The aggregated effect of both Education Scenarios on the future education composition is the same

Output

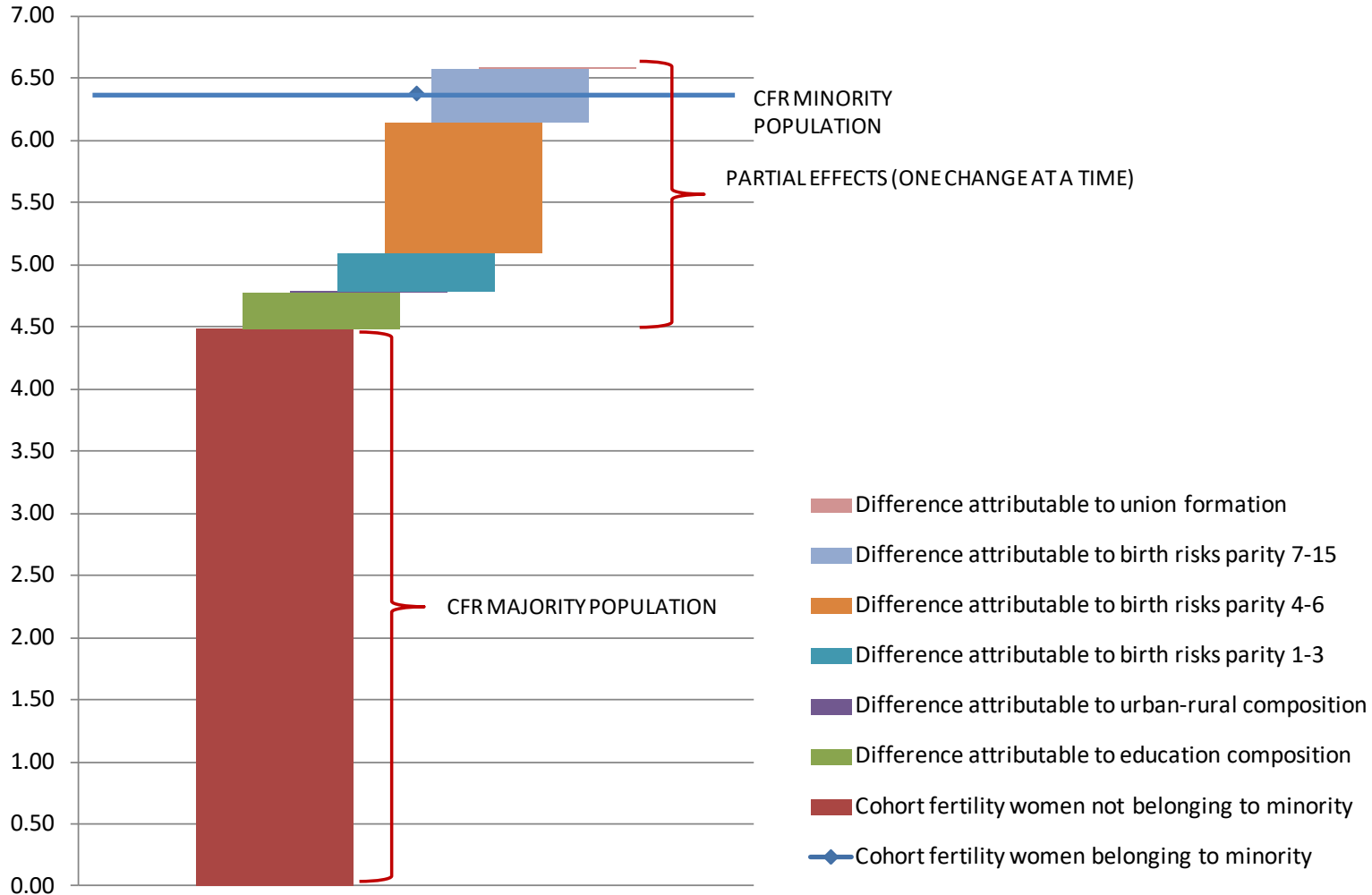
- **Decomposition:** which processes contribute to which extent to the different cohort fertility between the minority and majority population
- **What-if analysis:** demographic down-stream effects of educational investments: cohort fertility and experience of child deaths for three generations of women
- **Population projection:** urban and rural population size in 2100 by minority status for the three scenarios

Output: Decomposition

- Simulated difference in cohort fertility of next generation between minority and majority is ~2 births (6.4 versus 4.5)
- **Analysis example:** 60% higher union formation hazards in minority population.
- **Simulation:**
 - The higher union formation hazard in average leads to a one year earlier union formation but has no effect on differences in cohort fertility
 - Half of the fertility difference can be attributed to differences in 4th to 6th births

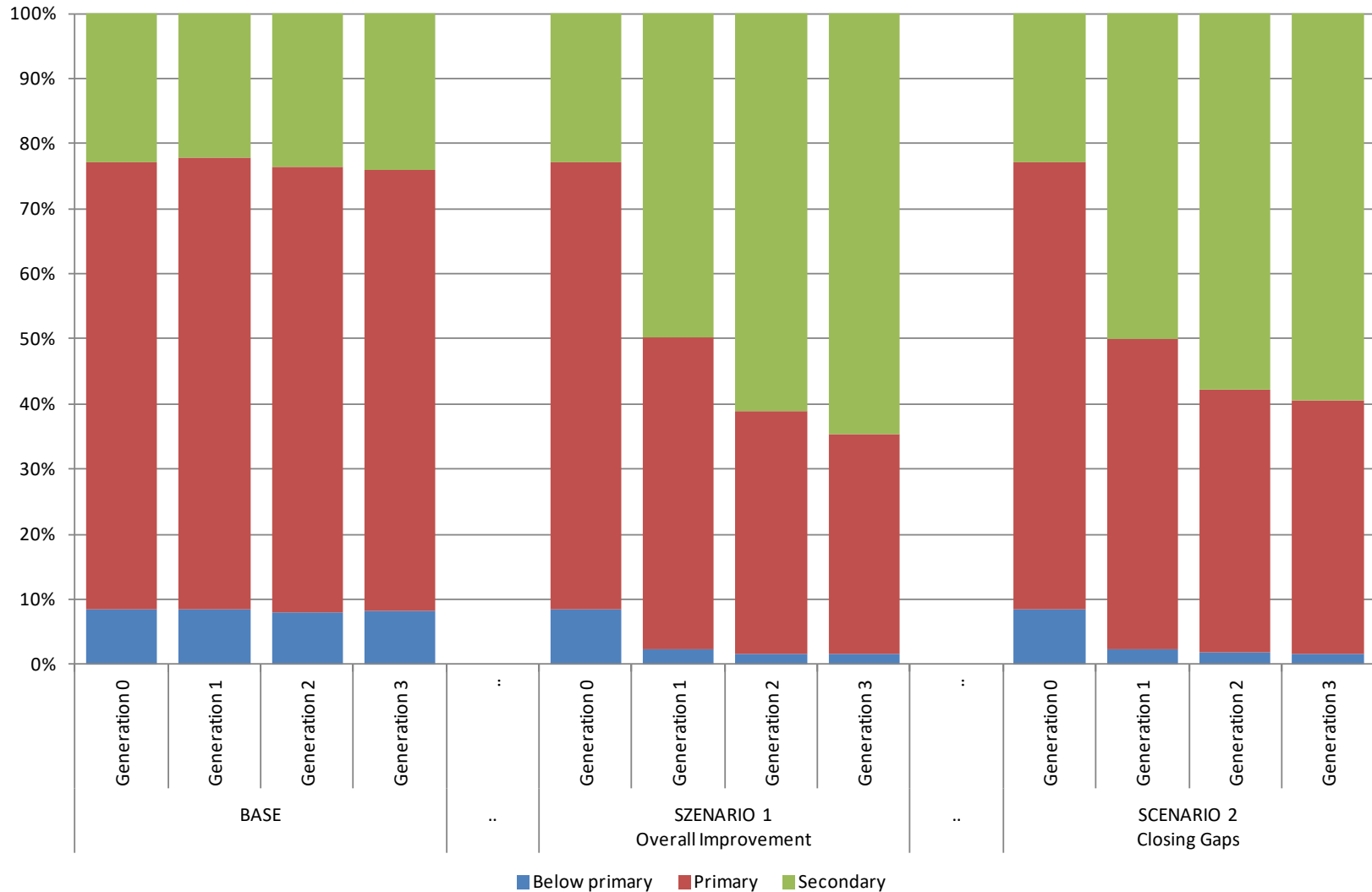
Output: Decomposition

DE-COMPOSITION COHORT FERTILITY RATE (CFR) - MINORITY VERSUS MAJORITY



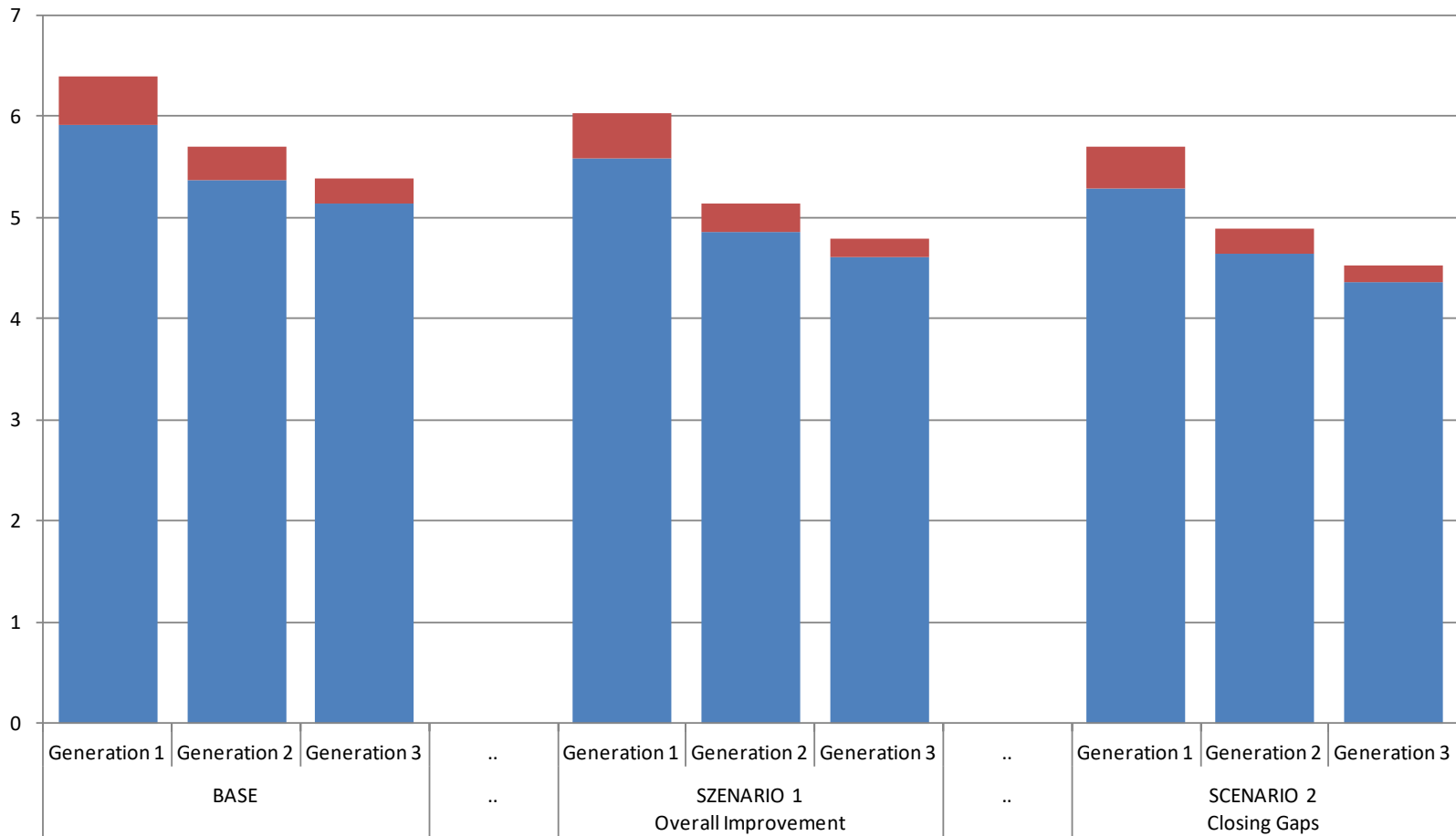
What-if analysis - Education

EDUCATION COMPOSITION BY GENERATION AND POLICY SCENARIO - ALL



What-if analysis – CFR & mortality

COHORT FERTILITY OF WOMEN SURVIVING TO AGE 15 - MINORITY

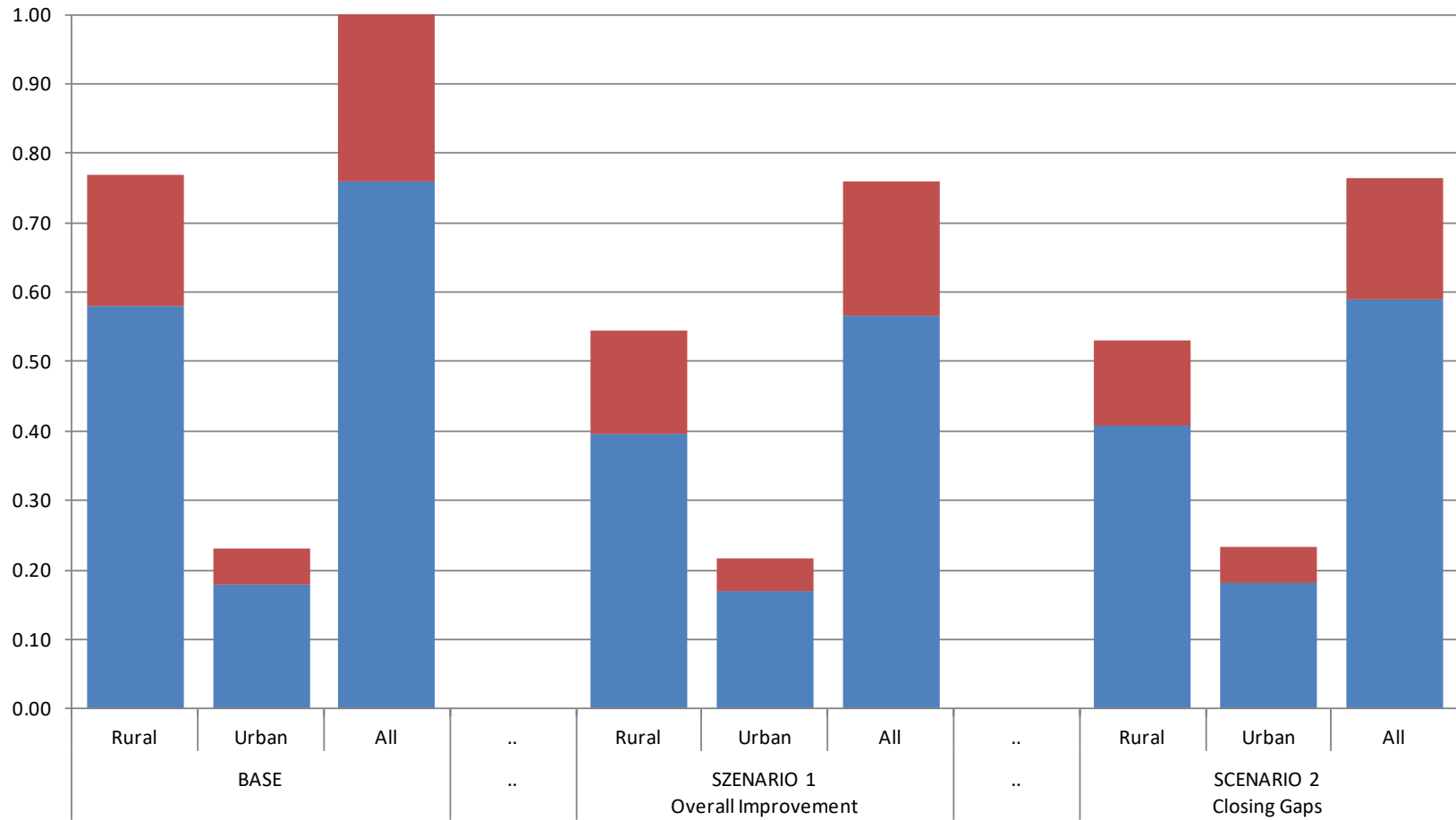


■ Children surviving until age 10

■ Children not surviving until age 10

Population projection 2100

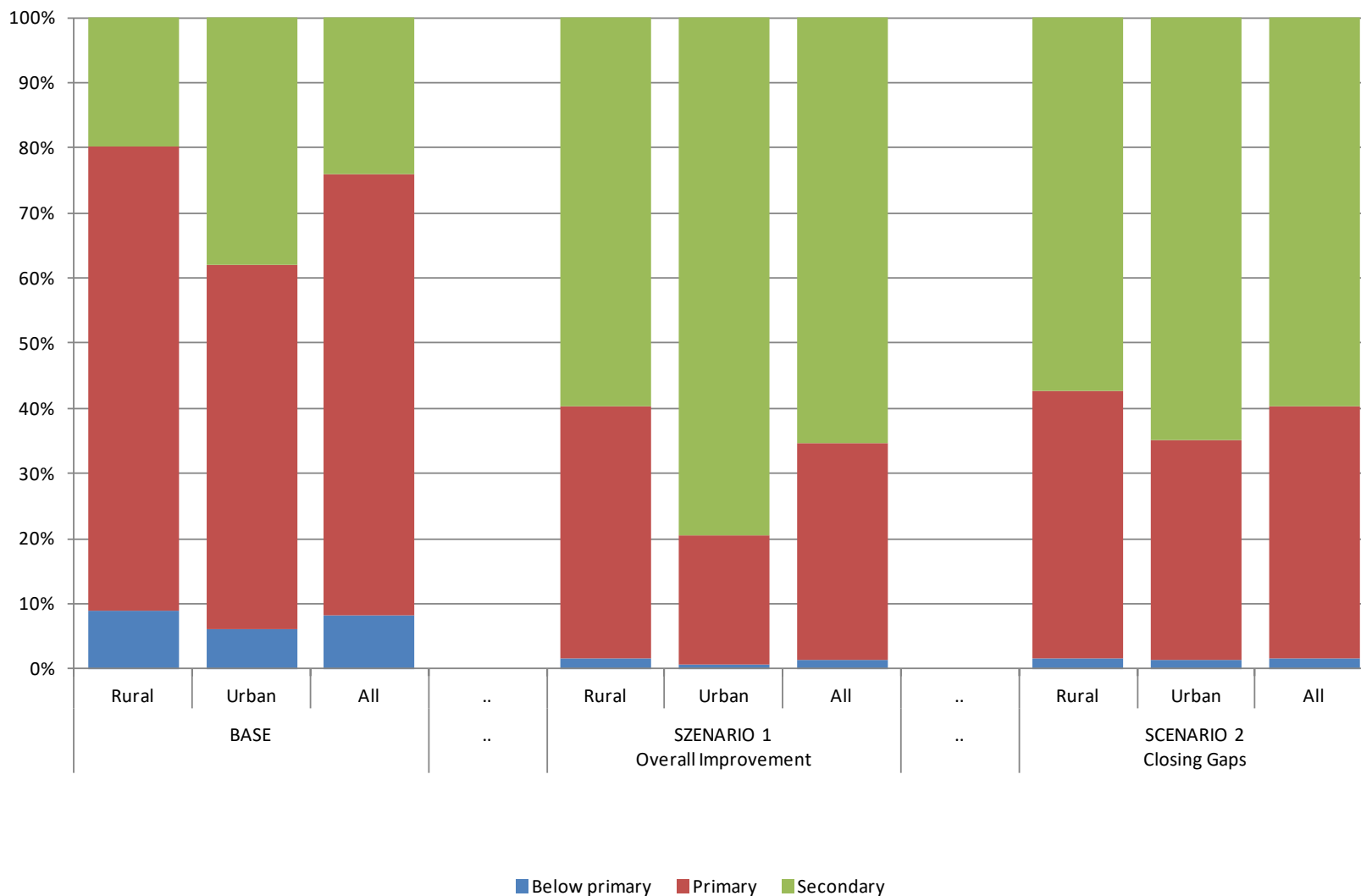
FEMALE POPULATION AGE 18-49 IN 2100 (Base Scenario = 1)



■ Majority ■ Minority

Education projection 2100

EDUCATION DISTRIBUTION FEMALE POPULATION AGE 18-49 IN 2100



Implementation overview

- Implemented in **Modgen**, a freely available programming language developed and maintained at Statistics Canada and used in dozens of applications around the globe
- Modgen creates a stand-alone model executable program with a complete visual interface and detailed model documentation.
- Many of the underlying mechanisms like event queuing are hidden.
- Modgen translates Modgen code into C++. This allows to combine the strengths of the generic C++ language with specialized microsimulation language concepts and functions.
- Modgen includes a powerful tabling language and tools for visualizations.

Modgen: Features

- **All approaches:** Discrete, continuous; interacting or non-interacting populations
- **Fast:** compiled language, pre-compiled to C++
- **Multilingual** models possible
- Export of parameters and tables to Excel
- Unlimited dimensions for parameters and tables
- **Visualization** of individual life courses
- Common fully documented **user interface**
- **Scenario management**
- Automated generation of model **documentation**
- **Multi-threading** and grid-computing possible

Programming interface

The screenshot displays the Microsoft Visual Studio Academic interface for a project named 'microWB'. The Solution Explorer on the left shows the project structure, including folders for C++ Files, External Dependencies, and Modules (mpp). The code editor in the center shows the 'Mortality.mpp' file, which defines a module for mortality modeling. The code includes a note, a partition for age groups, a classification for mortality risks, and parameters for mortality rates and trends. The Output window at the bottom right shows the build process, including steps like 'Marking Up input files...', 'Creating output files...', and 'Removing special markup...'. The build was successful, resulting in 0 errors and 0 warnings.

```
//LABEL(Mortality, EN) Mortality Module

/* NOTE(Mortality, EN)
   This module models mortality which is driven by an age baseline as well as by relative risks
   depending on mother's education in young ages and own education later in life.
   Mortality is parameterized with recent rates from Malawi. Relative risks are derived from
   publications based on the Health and Fertility survey. Mortality is assumed to decrease over time
   at a rate of 1 percent per year.
*/

partition AGE_GR_MORT { 5, 10, 15, 20, 40, 60 };           //EN Age group

classification MORT_REL                                   //EN Relative mortality risks
{
    MR_LOW_EDUC,                                         //EN No primary education
    MR_HIGH_EDUC,                                       //EN Secondary education
    MR_URBAN,                                           //EN Urban
    MR_MINORITY                                         //EN Minority
};

parameters
{
    double MortalityRates[AGE_RANGE][SEX];              //EN Mortality Rates
    double MortalityRelRisks[AGE_GR_MORT][MORT_REL];    //EN Relative mortality risks
    double MortalityTrend[SIM_YEARS];                   //EN Mortality trend
};
```

Output

```
Show output from: Modgen 11
Marking Up input files ...
Creating output files ...
Removing special markup ...
Mapping symbols to modules ...
Modgen: 0 errors - 0 warnings
```

Item(s) Saved Ln 69 Col 32 Ch 26 INS

Model documentation

The screenshot shows a web browser window titled "microWB Encyclopedic Documentation". The browser's address bar shows "microWB 1.0.0.0 - Encyclopedic Documentation". The page content is as follows:

Module: Education

[Top](#) [Classifications](#) [Parameters](#) [Parameter Groups](#) [Ranges](#) [Parameters/Read](#) [Simple/Read](#) [Simple/Set](#)

Note:

This module implements education progressions. Education levels distinguished in the model are below primary, primary, and secondary education. Probabilities to graduate from primary respectively secondary education depend on mother's education, urban-rural setting, minority status, and a time trend. Parameters of this module were chosen for demonstrational purposes only. In the base scenario they leave the education composition of the population stable; The two policy scenarios implement two types of educational interventions: The first improves the odds to reach higher education for everybody while leaving differences by mothers' education, urban-rural setting and minority status as in the base scenario. The second scenario closes gaps between rural and urban rates as well as between the minority and the majority population while the differences by mothers' education are reduced by 50 percent.

Classifications:

| Name | Label |
|----------------------------|------------------------|
| EDUC | Education level |
| EDUC_PARA | Education Parameters |
| EDUC_TRANS | Education transmission |

Parameters:

| Name | Label |
|-------------------------------------|------------------------|
| EducationParameters | Education transmission |

The left sidebar of the browser window shows a tree view of the documentation structure:

- microWB
 - Actors
 - Actor sets
 - Parameters
 - Parameter Groups
 - Modules
 - Births
 - CalendarClock
 - Education**
 - MicrodataHandling
 - microWB
 - Mortality
 - PersonCore
 - StartingPopulation
 - TableOutput
 - TickerCore
 - TrackingOutput
 - Unions
 - Urbanization
 - Tables
 - Types

User Interface

The screenshot displays the microWB software interface. On the left is a hierarchical tree view of the model structure. The main workspace shows a parameter table for 'Higher order births' and a summary table for 'Experience of women (ever 15)'.

Parameter: Higher order births

Rows: Columns:
Parameters for births: Birth Number

| | 2. Birth | 3. Birth | 4. Birth | 5. Birth | 6. Birth | 7. Birth | 8. Birth | 9. Birth | 10. Birth | 11. Birth | 12. Birth |
|---------------------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|-----------|
| Period 1 | 0.02646 | 0.02364 | 0.01968 | 0.02462 | 0.01947 | 0.02360 | 0.01987 | 0.02062 | 0.01430 | 0.01287 | 0.01190 |
| Period 2 | 0.45383 | 0.39610 | 0.34571 | 0.33475 | 0.32181 | 0.28745 | 0.27737 | 0.25762 | 0.22328 | 0.20095 | 0.18150 |
| Period 3 | 0.69179 | 0.64819 | 0.56251 | 0.49957 | 0.45878 | 0.38700 | 0.29497 | 0.24647 | 0.19066 | 0.17159 | 0.15150 |
| Period 4 | 0.29548 | 0.28412 | 0.24475 | 0.19957 | 0.15649 | 0.12803 | 0.11570 | 0.08638 | 0.05578 | 0.05020 | 0.04150 |
| Period 5 | 0.15861 | 0.10952 | 0.09288 | 0.09318 | 0.08194 | 0.03799 | 0.02475 | 0.01583 | 0.02940 | 0.01424 | 0.01150 |
| Period 6 | 0.03174 | 0.02376 | 0.03068 | 0.02714 | 0.02309 | 0.02103 | 0.02643 | 0.01521 | 0.00000 | 0.00000 | 0.00000 |
| Primary Education | 0.9881 | | | | | | | | | | |
| Secondary Education | 0.6521 | | | | | | | | | | |
| Minority studied | 1 | | | | | | | | | | |
| Urban | 0.8191 | | | | | | | | | | |

Table: Experience of women (ever 15) (out of date)

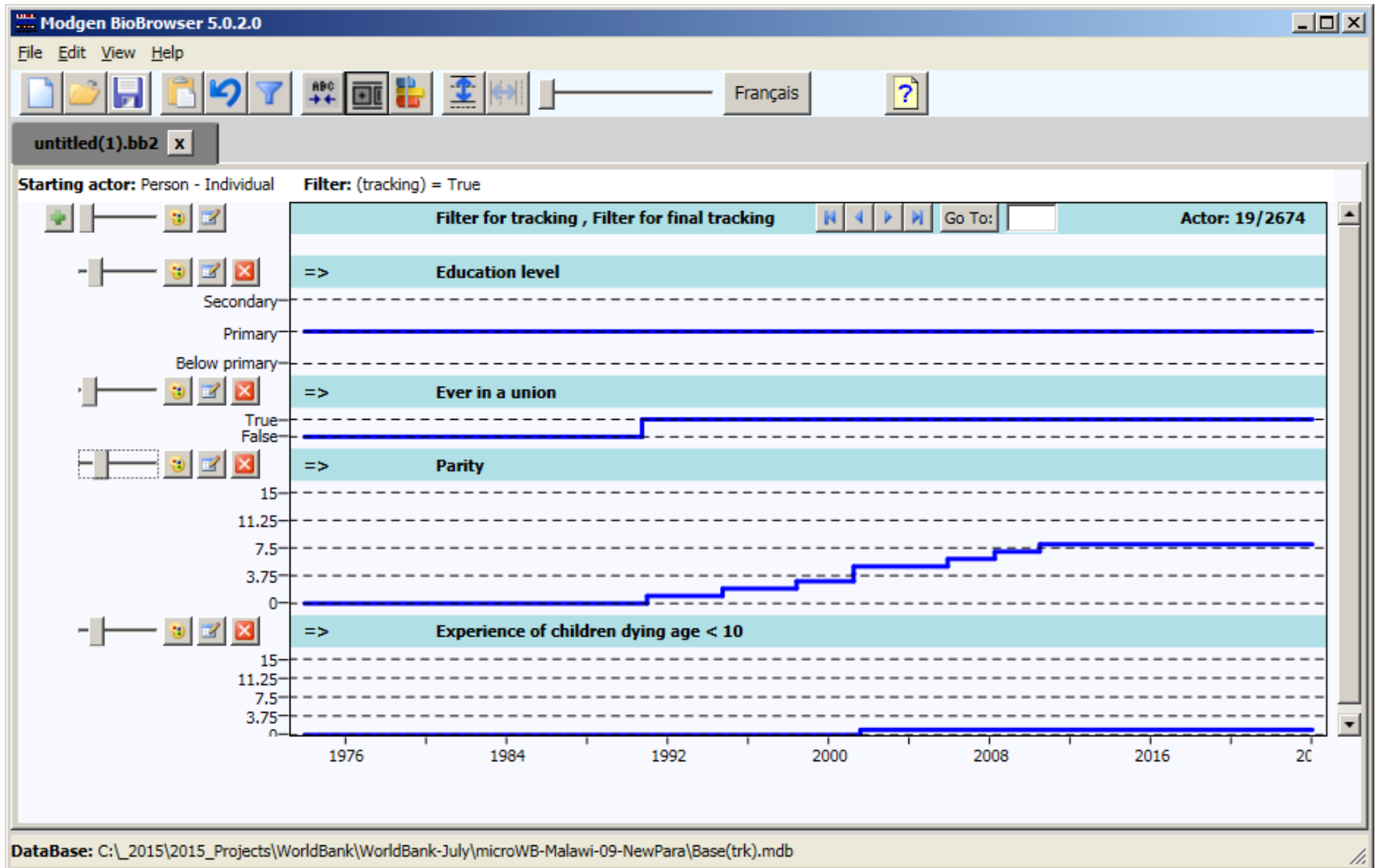
Transformation: Value

Urban Rural: Minority: Education level: Rows: Columns:
 Selected Quantities: Generation

| | Generation 1 | Generation 2 | Generation 3 |
|--------------------------------------|--------------|--------------|--------------|
| Number of women | 1025 | 1952 | 3515 |
| Average parity | 5.27 | 4.63 | 4.33 |
| Average number of children dead < 10 | 0.38 | 0.22 | 0.19 |

Ready NUM

BioBrowser



Code: dimensions & parameters

```
range      AGE_RANGE { 0, 100 };           //EN Age range
range      SIM_YEARS { 2011, 2150 };      //EN Simulated years

partition  AGE_GR_MORT { 5, 10, 15, 20, 40, 60 }; //EN Age group

classification SEX
{
    MALE,                                   //EN Male
    FEMALE                                  //EN Female
};

classification MORT_REL                    //EN Relative mortality risks
{
    MR_LOW_EDUC,                            //EN No primary education
    MR_HIGH_EDUC,                           //EN Secondary education
    MR_URBAN,                                //EN Urban
    MR_MINORITY                              //EN Minority
};

parameters
{
    double MortalityRates[AGE_RANGE][SEX];  //EN Mortality Rates
    double MortalityRelRisks[AGE_GR_MORT][MORT_REL]; //EN Relative mortality risks
    double MortalityTrend[SIM_YEARS];       //EN Mortality trend
};
```

... resulting parameter tables

The image shows three overlapping windows from a software application, each displaying a different parameter table.

Window 1: Parameter: Mortality Rates
Rows: Age range
Columns: SEX

| | Male | Female |
|----|---------|---------|
| 0 | 0.0501 | 0.04147 |
| 1 | 0.00659 | 0.00623 |
| 2 | 0.00659 | 0.00623 |
| 3 | 0.00659 | 0.00623 |
| 4 | 0.00659 | 0.00623 |
| 5 | 0.0025 | 0.003 |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |
| 11 | | |

Window 2: Parameter: Relative mortality risks
Rows: Age group
Columns: Relative mortality risks

| | No primary education | Secondary education | Urban | Minority |
|---------|----------------------|---------------------|-------|----------|
| (min,5) | 1.1 | 0.60 | 0.86 | 1.25 |
| [5,10) | 1.1 | 0.60 | 0.86 | 1.25 |
| [10,15) | 1.0 | 1.0 | 1.0 | 1.0 |

Window 3: Parameter: Mortality trend
Columns: Simulated years

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 |
|--|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 0.990 | 0.980 | 0.970 | 0.961 | 0.951 | 0.941 | 0.932 | 0.923 | 0.914 | 0.904 | 0.895 | 0.886 | 0.878 | 0.869 | 0.860 | 0.851 | 0.842 |

Declaration of states and events

```
actor Person
{
    logical alive    = { TRUE };           //EN Alive
    logical ever_15 = ( integer_age >= 15 ); //EN Person 15+
    int     age_gr_mort = self_scheduling_split(age, AGE_GR_MORT); //EN Age group
    event   timeDeathEvent, DeathEvent;   //EN Death event
};
```

Implementation of events

```
TIME Person::timeDeathEvent()
{
    TIME dReturnValue = TIME_INFINITE;
    // baseline hazard
    double dHazard = MortalityRates[integer_age][sex];
    // relative risks
    if ( urban_rural == UR_URBAN ) dHazard = dHazard * MortalityRelRisks[age_gr_mort][MR_URBAN];
    if ( minority == M_MINORITY ) dHazard = dHazard * MortalityRelRisks[age_gr_mort][MR_MINORITY];
    if ( ( integer_age < 20 && mother_educ == E_NON ) || ( integer_age >= 20 && educ == E_NON ) )
        dHazard = dHazard * MortalityRelRisks[age_gr_mort][MR_LOW_EDUC];
    else if ( ( integer_age < 20 && mother_educ == E_SEC ) || ( integer_age >= 20 && educ == E_SEC ) )
        dHazard = dHazard * MortalityRelRisks[age_gr_mort][MR_HIGH_EDUC];
    // time trend
    if ( calendar_year >= MIN(SIM_YEARS) ) dHazard = dHazard * MortalityTrend[RANGE_POS(SIM_YEARS,calendar_year)];

    if ( ( ( person_type == PT_START && calendar_year >= 2010 ) || ( person_type == PT_SIM && calendar_year >= 1995 ) ) && dHazard > 0.0 )
    {
        dReturnValue = WAIT( -log(RandUniform(5)) / dHazard );
    }
    if ( dReturnValue > time_of_birth + MAX(AGE_RANGE) )
    {
        dReturnValue = time_of_birth + MAX(AGE_RANGE);
    }
    return dReturnValue;
}

void Person::DeathEvent()
{
    alive = FALSE;
    if ( lMother != NULL && age <= 10 ) //age <=10 and the mother is still alive
    {
        //increment the mother's counter of experienced child death events
        lMother->child_deaths10++;
    }
    Finish();
}
```

Table definitions

```
table Person DeadChildren10_ever15_3GEN //EN Experience of women (ever 15) 3 GEN
[ trigger_transitions(alive,TRUE,FALSE) && sex == FEMALE && generation >= 1 && generation <= 3 && ever_15 ]
{
  urban_rural+ *
  minority+ *
  educ+ *
  {
    unit, //EN Number of women
    value_in(parity)/unit, //EN Average parity decimals=2
    value_in(child_deaths10)/unit //EN Average number of children dead < 10 decimals=2
  }
  * gen1to3
};
```


... resulting table

Transformation: Value

Urban Rural: Minority: Education level: Rows: Columns:

Rural Not belonging to minority Below primary Selected Quantities Generation

| | Generation 1 | Generation 2 | Generation 3 | |
|--------------------------------------|--------------|--------------|--------------|--|
| Number of women | 1025 | 1887 | 1046 | |
| Average parity | 5.27 | 4.63 | 4.29 | |
| Average number of children dead < 10 | 0.38 | 0.23 | 0.20 | |

Infos

- Modgen is freely available from Statistics Canada but it requires the Microsoft Visual Studio 10 Package
- An open-source implementation of Modgen openM++ is available (soon)
- The model and its code is available for training purposes; there is also a paper draft documenting the model