THE DEMOGRAPHIC TRANSITION

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D. Kauffman, Spring 2011

SUBMISSION INFORMATION

Systems Thinking
Term Model: The Demographic Transition
D. Kauffman, Spring 2011

Documents as part of this package

1. Model Sheet (this document)
2. Vensim: The Demographic Transition (Nigeria)
3. Data: Demographic Transition Data
    a. This data was collected by the authors. Age Specific Birth Rates.
4. Data: Death Rates per Age Segment aka ASMR
    a. This data was collected by the authors and we manually calculated ASMR based on the population of 2005 and 2010.
5. The Original Article

Data collected

- Age specific birth rates
- Crude death rate
- Infant Mortality Rate (death rate <1 year old)
- Under 5 Mortality Rate
- Western Country Mortality Rate (US)
- Calculated ASMR from population pyramid data 2005 & 2010.

Data Sources

- CIA Factbook
- Data.UN.Org: http://data.un.org/Data.aspx?d=GenderStat&f=inID%3A13
- IndexMundi
- Census.gov (population pyramids)

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CITATION: THE DEMOGRAPHIC TRANSITION

In the early 19th century, Thomas Malthus released a book titled, "An Essay on the Principle of Population[1]". The book predicted population would reach a limit and only attain sustainable levels through the introduction of particular checks. Malthus believed positive checks like disease and war in combination with preventive checks like abortion and birth control would have the biggest effect on societal change[2]. In the 21st century, since Malthus's time, the population is still increasing, however at a decreasing rate in part due to checks within the demographic system. Though Malthus stated, "The power of population is indefinitely greater than the power in the earth to produce subsistence for man[3]", food scarcity has not yet stopped human population growth, even though medical improvements have substantially increased the human lifespan[4].

We have avoided a global Malthusian nightmare in part because of a rapid and very fortunate increase in agricultural productivity in the 20th Century, but also because of the so-called "demographic transition," the name given to the dramatic drop in birth rates that most societies experience after several generations of increased life expectancy and standard of living. The purpose of this paper is to model the demographic transition from a systems standpoint in order to understand the population changes from the past and account for probable shifts in the future.

The United States Census Bureau estimates that world population will reach 7 billion in 2011[5]. The number of humans living on Earth has expanded exponentially since the onset of the current era (See Exhibit A). This rapid period of expansion is attributed to technological development and exponential

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[1] Landsburg, Lauren F. "Thomas Robert Malthus." *Library of Economics and Liberty*. The Concise Encyclopedia of Economics, 2008. Web. 24 Nov. 2011. <http://www.econlib.org/library/Enc/bios/Malthus.html>.
[2] Geoffrey Gilbert, Introduction to Malthus T.R. 1798. *An essay on the principle of population.* Oxford's World Classics reprint, viii
[3] Rowe, John F. "Bicentennial Malthusian Essay." *Home*. Ed. Sharon McCloe Stein. Minnesotans For Sustainability, Aug. 1998. Web. 24 Nov. 2011. <http://www.mnforsustain.org/rohe_j_malthusian_bicentennial_essay.htm>.
[4] Geoffrey Gilbert, Introduction to Malthus T.R. 1798. *An essay on the principle of population.* Oxford's World Classics reprint, viii
[5] EarthSky. "Feeding the World While Protecting the Planet." *EarthSky.org*. 16 Oct. 2011. Web. 24 Nov. 2011. <http://earthsky.org/food/feeding-the-world-while-protecting-the-planet>.

growth theories. In 2004, the United Nation projected the global population to reach between 7.5 and 10.5 billion by the year 2050 (See Exhibit B)[6]. These projections illustrate a continued increase of total world population coupled with a steady decline in the total population growth rate. The largest human growth is attributed to developing and underdeveloped nations within Asian and African nations (See Exhibit C).

Exhibit A: Human Population over Time

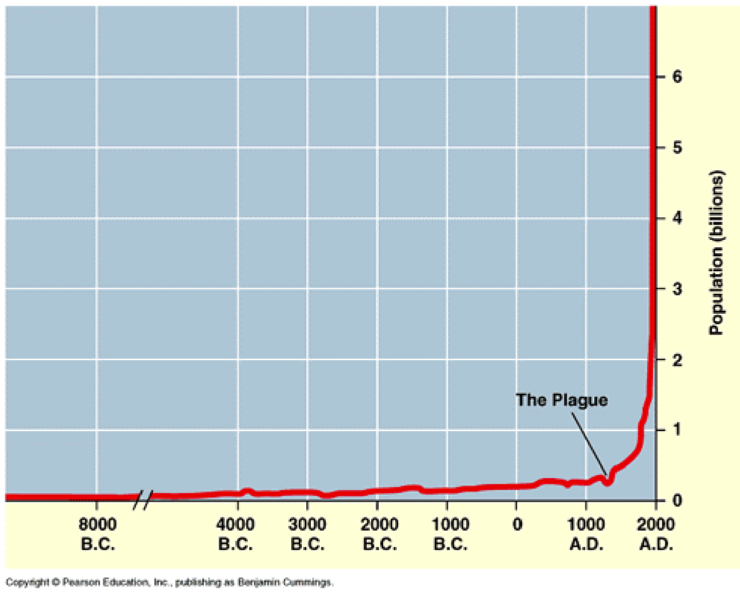


Exhibit B: Estimated World Population 1950-2000, and projections; 2000-2050[7]

[6] http://www.un.org/esa/population/publications/longrange2/WorldPop2300final.pdf
[7] Ibid.

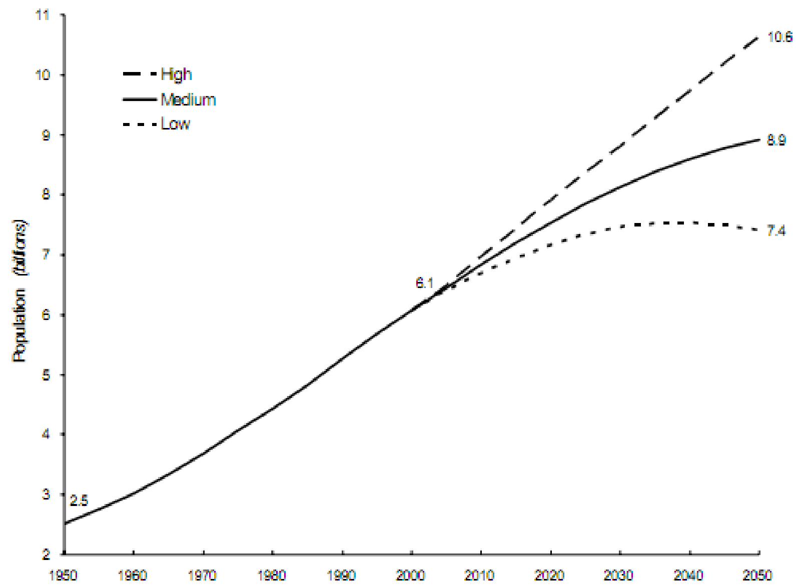
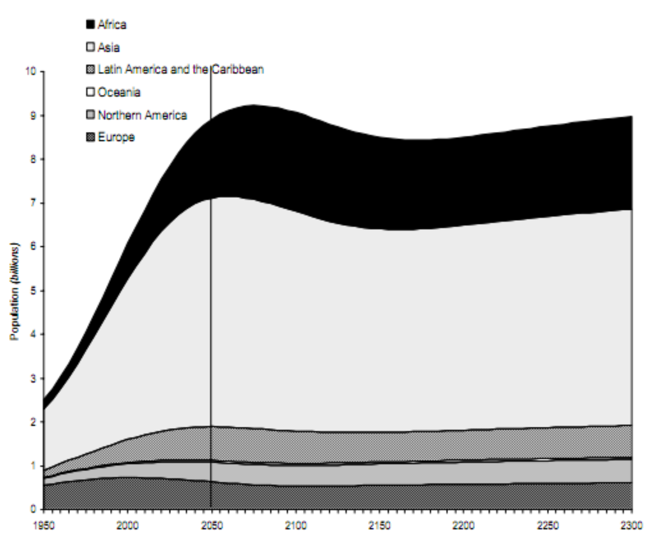


Exhibit B: Population in Major Areas, Estimates and Medium Scenario: 1950-2300[8]

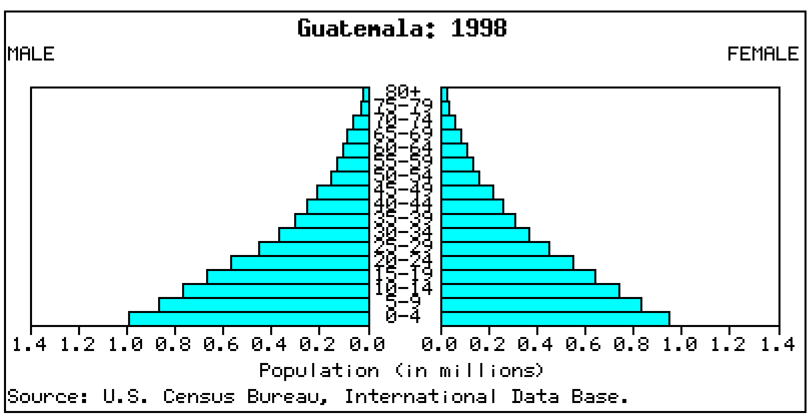


Why are some (e.g. Asian and African) countries projected to grow more than others (e.g. European or American nations)? The phenomenon that explains the variance between population growth between developed, developing and underdeveloped nations is referred to as the "demographic transition". The demographic transition theory was developed by demographer, Warren Thompson, who observed birth

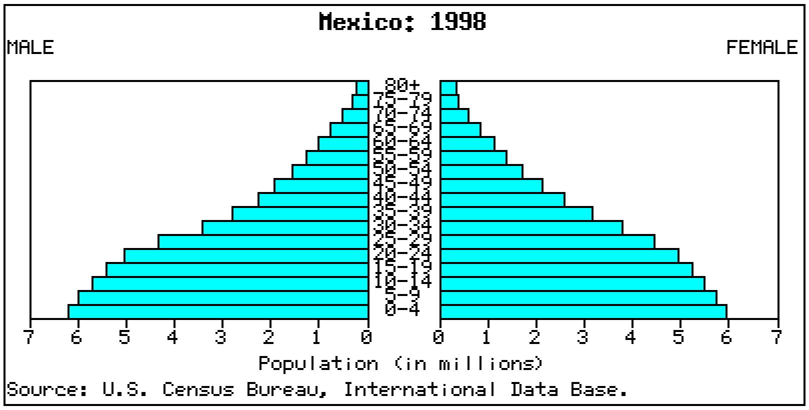
[8] http://www.un.org/esa/population/publications/longrange2/WorldPop2300final.pdf

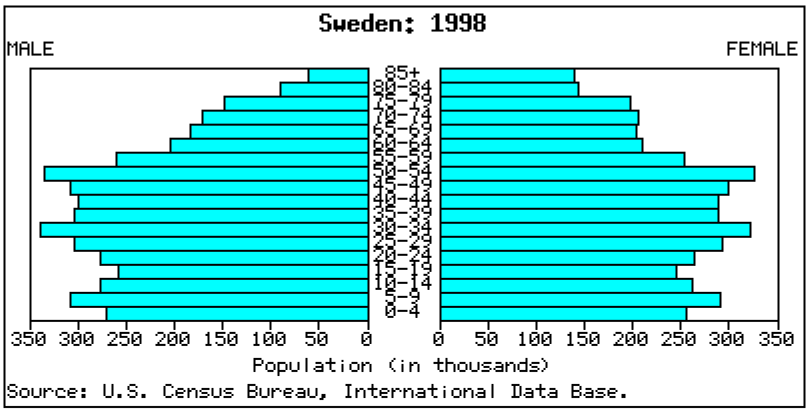
and death rates over a period of 200 years. It characterizes the evolution from a society with high birth rates and death rates to one with low birth rates and death dates. Not only are technological improvements significant in understanding population shifts, but also cultural ideas about topics like birth control, marriage and education. Population size and growth is closely linked with the country specific economies and reflects the differences between OECD and non-OECD nations. Demographers generally divide the transition into four phases, as described below, and there is a correlation between phase and economic development. For instance, developed societies are typically in stage 3 or 4, developing nations stage 2 or 3 and underdeveloped nations stage 1 of the demographic transition. The Population Pyramids in Exhibit D are visual illustrations of how drastically population varies at each stage of the demographic transition.

Exhibit D: Population Pyramids for Guatemala, Mexico and Sweden[9]



[9] Montgomery, Keith. "The Demographic Transition." *University of Wisconsin-Marathon County*. Department of Geography and Geology. Web. 24 Nov. 2011. <http://www.marathon.uwc.edu/geography/demotrans/demtran.htm>.





A typical stage 1 country with the same total population as Guatemala, but with much higher infant and youth mortality rates, would be represented by a pyramid much wider at the bottom and even narrower at the middle and top than the Guatemalan pyramid, with the number of 0-4 year olds being almost 10 times the number of 25-29 year olds. As infant and child mortality rates decrease we begin to see the pyramid climb, showing an increase of overall population, as show by the Guatemala pyramid. Social cues for large families remain, keeping the birth rate high. This results in an overall increase of the population. It takes at least one and a half generations of low mortality rate combined with a high birth rate to shift these social cues, reducing the desire to have large families, however during this time the population continues to rise due to population momentum. This is shown with the Mexico pyramid. Finally, Sweden illustrates the final stage where the birth rate drops below the death rate for a net population reduction. Many European countries are in Stage 4.

THE FOUR STAGES OF THE DEMOGRAPHIC MODEL

The stages of the demographic transition are as follows:

Stage 1: Highly cyclic
Stage 2: Population Rise
Stage 3: Population Growth due to Momentum
Stage 4: Population Stabilizes or Declines

Stage One of the demographic transition is characterized by highly cyclic patterns of birth and death. The high death rate (30-50/1000) is primarily due to factors like food shortages and diseases that stem from poor hygiene and lack of clean water. Consequently, the birth rate (30-50/1000) must also remains high in Stage One as mothers have as many children as possible in order to support the family unit. Because of the death rate, only a small fraction of infants survive. Desired family size may be 12 or more, but the vast majority of the children who are born will die with no living descendents.

Stage Two represents a rise in population. Due in part to improvements in food supply and public health the death rate decreases. At the same time, cultural expectations for total births continue unchanged so the crude birth rate remains high, or even increases as maternal mortality drops and other factors change child-rearing practices. (For example, the availability of infant formula reduces maternal nursing of infants, which can substantially reduce the average interval between pregnancies.) Increased literacy and public health education also aid in reducing infant and childhood mortality rates. So, this society is one in which there are more mothers reproducing and fewer children dying. The death rate has fallen, but the birth rate remains at very high levels.

In **Stage Three**, population continues to grow because of existing momentum in the system. The death rate has substantially decreased, but now the birth rate is also decreasing. A variety of factors (such as the exposure to television and other popular media, increased female literacy, and the shared experience of being part of very large families with many surviving siblings) together create new cultural norms regarding reproduction and birth control. In most such societies, children have also shifted from being a monetary asset in terms of labor for a family to a net drain on family resources. The cost of educating children and providing living expenses often deters women from having more children than the family can support.

Finally, **Stage Four** of the demographic transition illustrates a society in which the birth rate and death rate are both very low and the population is stable or declining. Birth rates are at or below replacement levels (2.1 children/ family). The society also gets much greyer, as the percentage of young people declines, the percentage of old people increases, and the average age of the population rises.

As the world's academics, corporate leaders, and politicians consider the implications of issues like climate change, food preferences, resource constraints, energy, healthcare costs, and educational programs they must realize that these debates tie into the larger population system. Understanding how the shift in population patterns affects the larger global system creates a language to influence human demographics, for better or worse.

STAGES AND EXAMPLE COUNTRIES

Per 1000 population

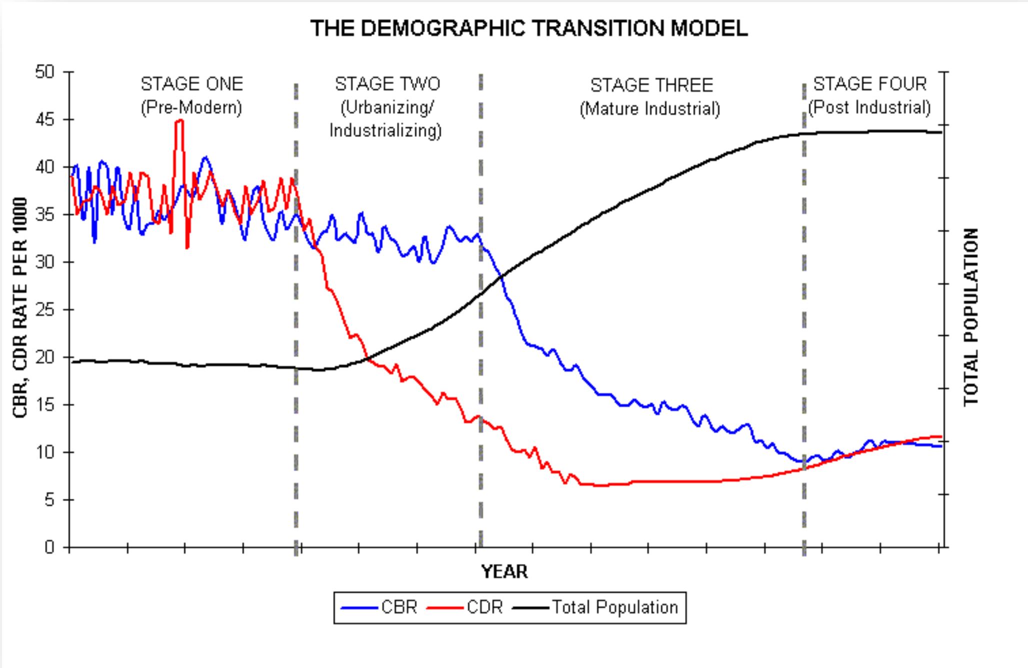
Stage	Country	2003 Birth	2003 Death	2011 Birth	2011 Death
1	Nigeria	38	13.7	35.5	16
2	Guatemala	35	6.7	26.9	4.9
3	Mexico	21.9	4.9	19.1	4.8
4	Sweden	9.7	10.5	10.1	10.2

MODEL VARIABLES

- Desired Family Size
  - Net change
  - Threshold
  - Rate of Change
- Desired Birth Rate
  - Birth Factor
- General Mortality Factor
  - Mortality Reduction
  - Mortality Reduction Rate
- Mother to Daughter Ratio
  - Moms
  - Daughters
- Total Population
  - Females Aged 0-4
    - Population 0-4
    - Age Specific Death Rate (ASDR) 0-4
    - Death Rate 0-4
    - Deaths 0-4
    - Survivors 0-4
  - Females Aged 5-9
    - Population 5-9
    - ASDR 5-9
    - Death Rate 5-9
    - Deaths 5-9
    - Survivors 5-9
  - Females Aged 10-14
    - Population 10-14
    - ASDR 10-14
    - Death Rate 10-14
    - Deaths 10-14
    - Survivors 10-14
  - Females Aged 15-19
    - Population 15-19
    - ASDR 15-19
    - Death Rate 15-19
    - Deaths 15-19
    - Survivors 15-19
    - Births to 15-19
  - Females Aged 20-24
    - Population 20-24
    - ASDR 20-24
    - Death Rate 20-24
    - Deaths 20-24
    - Survivors 20-24
    - Births to 20-24
  - Females Aged 25-29
    - Population 25-29
    - ASDR 25-29
    - Death Rate 25-29
    - Deaths 25-29
    - Survivors 25-29
    - Births to 25-29
  - Females Aged 30-34
    - Population 30-34
    - ASDR 30-34
    - Death Rate 30-34
    - Deaths 30-34
    - Survivors 30-34
    - Births to 30-34
  - Females Aged 35-39
    - Population 35-39
    - ASDR 35-39
    - Death Rate 35-39
    - Deaths 35-39
    - Survivors 35-39
    - Births to 35-39
  - Females Aged 40-44
    - Population 40-44
    - ASDR 40-44
    - Death Rate 40-44
    - Deaths 40-44
    - Survivors 40-44
    - Births to 40-44
  - Females Aged 45-49
    - Population 45-49
    - ASDR 45-49
    - Death Rate 45-49
    - Deaths 45-49
    - Survivors 45-49
    - Births to 45-49
  - Females Aged 50-54
    - Population 50-54
    - ASDR 50-54
    - Death Rate 50-54
    - Deaths 50-54
    - Survivors 50-54
  - Females Aged > 55
    - Population> 55
    - ASDR> 55
    - Death Rate> 55
    - Deaths> 55
    - Survivors> 55

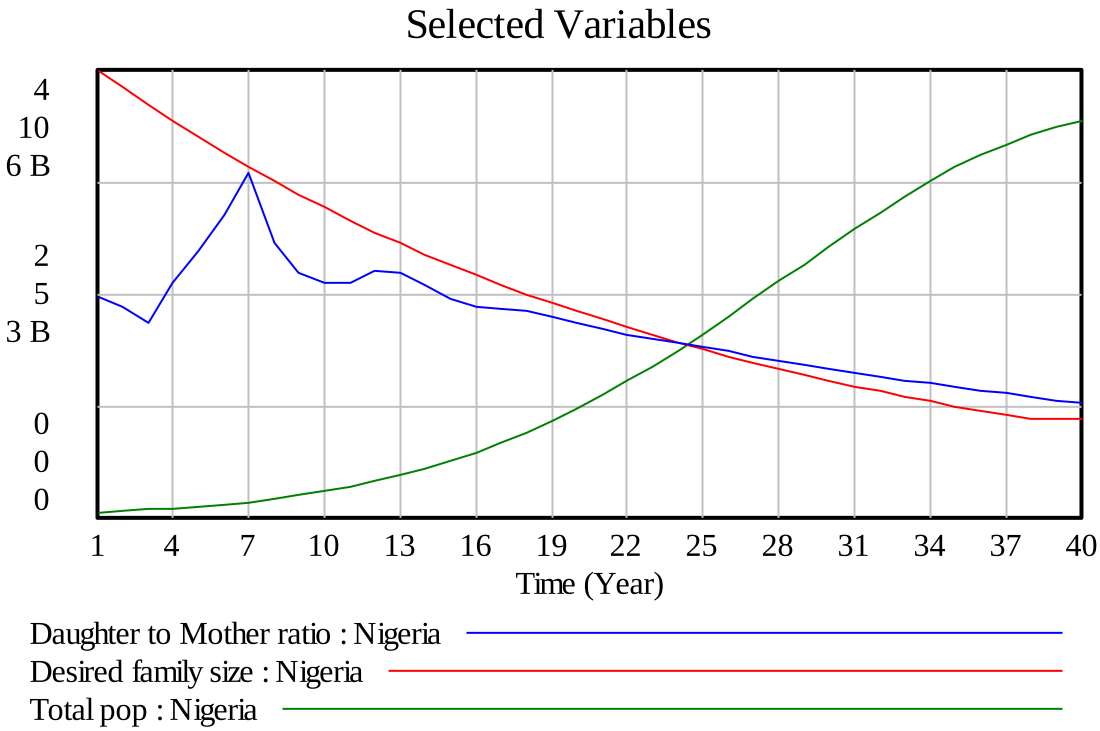
BEHAVIOR OVER TIME (BOT)

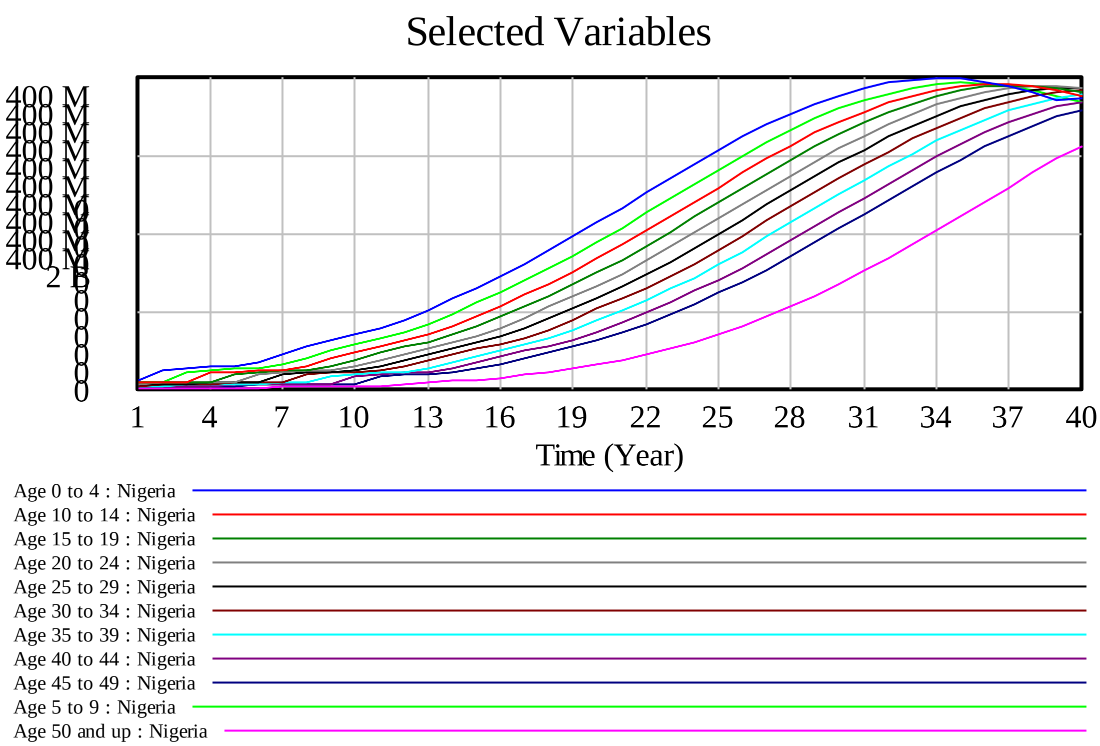
ESTIMATED

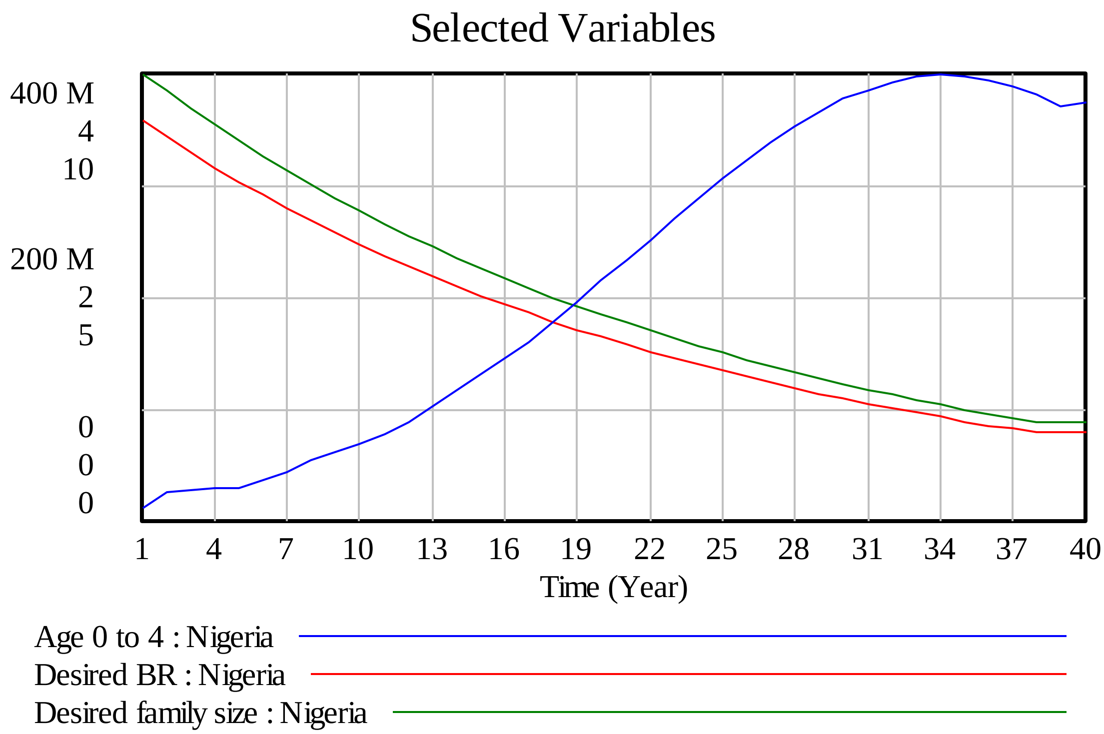


[CBR = Crude birth rate. CDR = Crude birth rate.]

ACTUAL


Selected Variables
4
10
6 B
2
5
3 B
0
0
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40
Time (Year)
Daughter to Mother ratio : Nigeria
Desired family size : Nigeria
Total pop : Nigeria


Selected Variables
400 M
2 B
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40
Time (Year)
Age 0 to 4 : Nigeria
Age 10 to 14 : Nigeria
Age 15 to 19 : Nigeria
Age 20 to 24 : Nigeria
Age 25 to 29 : Nigeria
Age 30 to 34 : Nigeria
Age 35 to 39 : Nigeria
Age 40 to 44 : Nigeria
Age 45 to 49 : Nigeria
Age 5 to 9 : Nigeria
Age 50 and up : Nigeria



THE MODEL

This systems model illustrates the demographic transition when considering female populations. The basic model presented will be used in conjunction with historical data to show differences across demographic transition stages. In particular, the population data for Nigeria, Guatemala and Sweden is included within the report. Nigeria is used as specific case study for modeling parametric change. Moreover, the introduction of literacy demonstrates the effect of a structural change within the existing system.

Before delving into the comprehensive model narration, let us first consider from a basic level how the system operates. We begin with a population with a high birth rate and high death rate. Economic, social, and technological improvements steadily extend lifespan, and the death rate is thereby reduced across the entire population. At the beginning of the demographic transition, females reproduce above the replacement rate because there is (A) a chance of death, (B) few birth control options and (C) little female education. Total population and female population increase. As education and birth control are introduced to society, the birth rate decreases, but population still grows rapidly because of the large growth in the previous cohorts. Eventually, population levels and, if childbirth falls below replacement rate, total population from cohort to cohort may even decline. We are left with a population exhibiting low birth and death rates.

DEMOGRAPHIC TRANSITION MODEL VARIABLES AND NARRATION

This systems model considers the following variables and behaviors as key in understanding the essential theory of the demographic transition. To begin with, we chose to model only the female portion of the population, because history has shown that the male population can vary widely – e.g., in the aftermath of major wars - without affecting the birth rate. The number of daughters per mother is a much better predictor of population growth than the number of children per family.

The heart of the model is a classic "bucket brigade" aging chain, in which the entire contents of each stock are transferred (with losses) to the next "bucket" at the end of each interval, which in this case is five years. The female population in the model is divided by age into 11 different stocks ranging from "Age 0-4" to "Age 50 and Up". (See Appendix for a detailed variable list).

On the right side of the model, each cohort stock is linked to a "Death Rate", "Age Specific Mortality Rate (ASMR)", and "Deaths", which in turn determine the number of "Survivors" per cohort. The crude death rate often used in demography is defined as the total number of deaths per year per 1000 people and it ignores the large differences created by the age structure of the population. By contrast, the ASMR refers to the total number of deaths per year per 1000 people of a given age. In the model, the ASMR for each cohort is combined with a "General Mortality Factor" to determine the number of deaths in that cohort during each 5 year period, and the total of these deaths determines the crude death rate for the population. We are assuming, in effect, that a change in general mortality has a proportionally equal effect on all ages. So, for instance if a new technology is introduced within society we can observe its impact by altering the "General Mortality Factor" variable.

The left side of the model is focused on "Desired Family Size" and the "Birth Rate". Beginning at cohort, "Age 15-19", birth rate per cohort is determined by factoring in the "Desired Birth Rate" which stems from "Desired Family Size". The "Mother to Daughter Ratio" influences the "Net Change" in "Desired Family Size". When daughters observe that less infants make it to adulthood they are inclined to have a greater number of children. Conversely, as more infants live to adulthood and it costs more to have a child the "Desired Family Size" decreases.

Desired family size is only part of the equation. Parents are also influenced by the number of births they believe it will take to achieve a particular completed family size. However, it's important to recognize that most women do not respond directly to mortality rate changes. A crucial point in modeling social behavior is to make sure that behavior only changes in response to information that people actually have and care about. In this case, an abstract number like the death rate is unlikely to be known to, or understood by, most people, and it is even more unlikely that they would take it into account in determining family size.

We therefore asked ourselves how and when mortality changes would impact the key decision-makers. One answer that makes sense is that parents are aware of how many siblings they have, and aware also of how many siblings other people of similar age have, and they can compare this with their idea of a desirable completed family size, and with their parents' intended family size.

In many Stage 1 societies, children provide a net economic contribution from an early age and are the only security for old age. In order to be fairly sure of having at least one child who lives long enough to support his or her aged parents, a family must often have 10 or more children. But if young adults look around them and see that most young adults have 5-10 living siblings, as is common in late Stage 2 and early Stage 3 societies, they are likely to conclude that they don't need to have as many children as their parents did in order to achieve their goals.

Because they are responding to the observable effects of family decisions made a generation earlier, there is therefore a considerable lag in their response to mortality changes. We designed this model in part to model this information lag, to see if it can explain much of the characteristic S-shape of the demographic transition. As a proxy for observable family size, we took the total female population aged 10 to 29 ("Daughters") and divided it by the total female population aged 30-49 ("Mothers") to create the "Daughter to Mother Ratio". We also used a Rate of Change variable to limit the amount of change in the Desired Family Size in a given period, based on the common observation that cultural norms are conservative. If people see that they don't need to have as many children as their parents did, they will want to have fewer children, but the meaning of "fewer" will not be calculated according to a precise ratio. Instead, it is likely to drift steadily lower over time until the discrepancy between desired and actual family size largely disappears. This model does a surprisingly good job of reproducing historical changes and modeling the demographic transition, even though it omits some of the key factors that are commonly used to explain that transition. We next attempted to see if it made a difference if we explicitly included changes to female literacy in the model.

On the following model, we added a fairly strong Literacy Factor, consistent with reports that this can be a fairly powerful contributor to changes in general health and reproductive behavior in developing countries. When the literary variable is added to the model, there is a reduction in infant mortality (the DR 0-4) and the General Mortality Rate as well as the desired birth rate. This initially increases population growth, as more children survive to adulthood, but also has a substantial negative effect on the birth rate, creating a net effect of a smaller overall population in the long run, easing the demographic transition from Stage 1 to Stage 4.

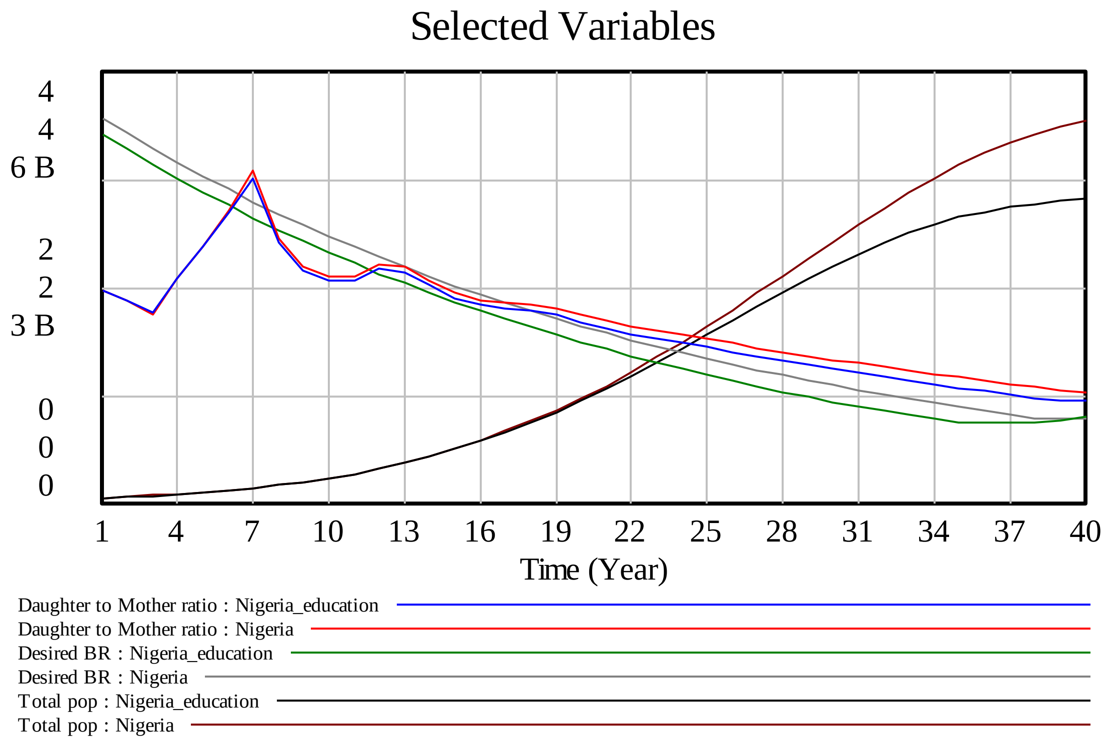
Variables Added

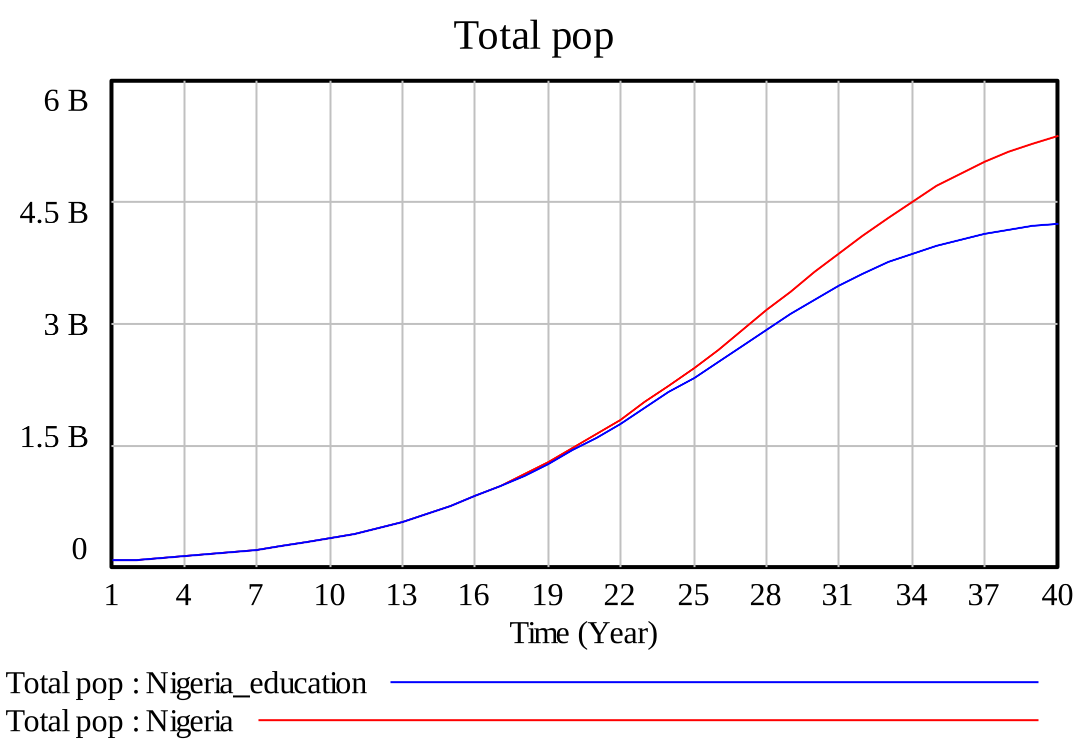
- Literacy Factor: Increasing the literacy of females in the population
- Literacy Multiplier: The effect of the literacy rate on the desired birth rate.

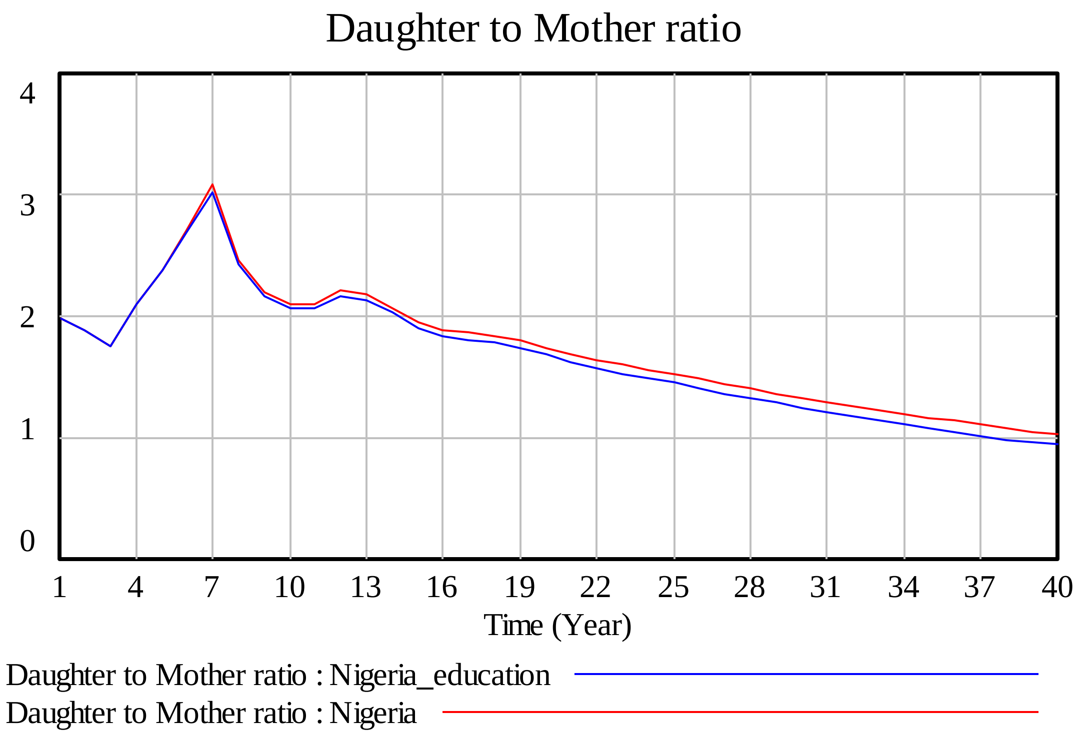
BA SELINE MODEL

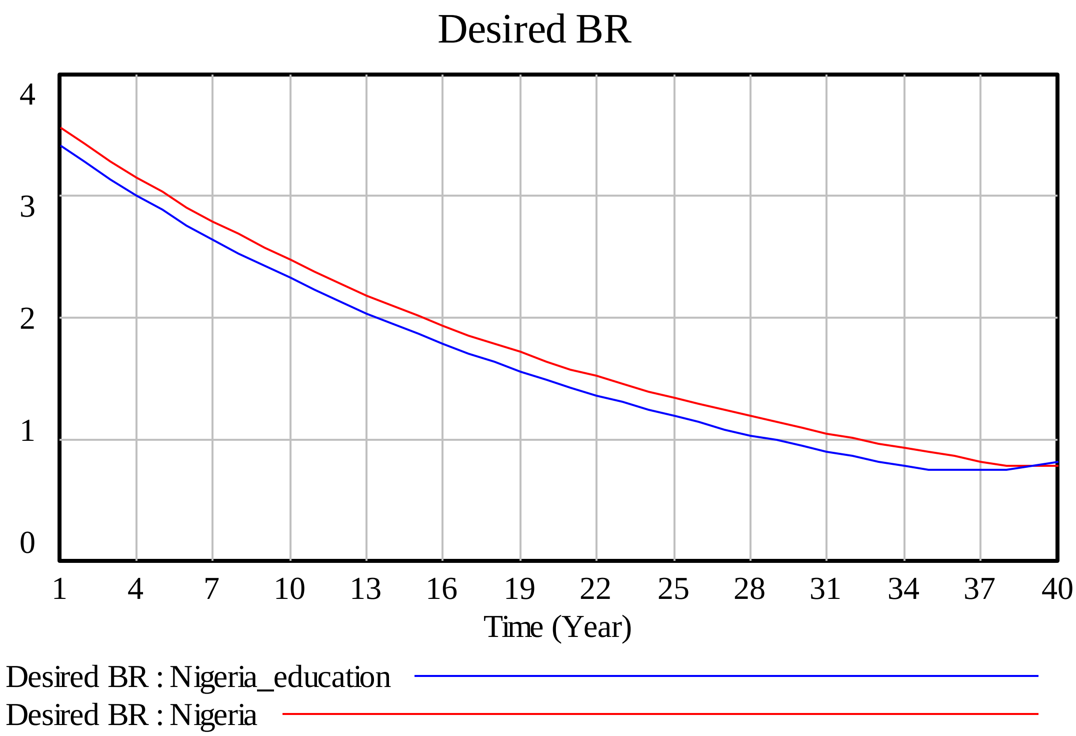
STRUCTURAL CHANGE: LITERACY VARIABLE ADDED

The graphs below allow the comparison of the results for the two models. As can be seen, the baseline model captures the essential dynamics of the transition and is adequate to explain the delay. Adding the literacy variable does not change the dynamic behavior of the model, but it does speed the transition significantly, suggesting that societies that do emphasize educational opportunities for women get a substantial demographic bonus for doing so.






Daughter to Mother ratio
4
3
2
1
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40
Time (Year)
Daughter to Mother ratio : Nigeria_education
Daughter to Mother ratio : Nigeria


Desired BR
4
3
2
1
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40
Time (Year)
Desired BR : Nigeria_education
Desired BR : Nigeria

EQUATIONS

BASELINE MODEL

(01) "30 and up"=
Moms+Age 50 and up
Units: **undefined**

(02) Age 0 to 4= INTEG (
Births 15 to 19+Births 20 to 24+Births 25 to 29+Births 30 to 34+Births 35 to 39
+Births 40 to 44+Births 45 to 49-Deaths 0 to 4-Survivors at 5,
1.15249e+007
)
Units: **undefined**

(03) Age 10 to 14= INTEG (
Survivors at 10-Deaths 10 to 14-Survivors at 15,
9.02656e+006
)
Units: **undefined**

(04) Age 15 to 19= INTEG (
Survivors at 15-Deaths 15 to 19-Survivors at 20,
7.95236e+006
)
Units: **undefined**

(05) Age 20 to 24= INTEG (
Survivors at 20-Deaths 20 to 24-Survivors at 25,
6.94984e+006
)
Units: **undefined**

(06) Age 25 to 29= INTEG (
Survivors at 25-Deaths 25 to 29-Survivors at 30,
6.03997e+006
)
Units: **undefined**

(07) Age 30 to 34= INTEG (
Survivors at 30-Deaths 30 to 34-Survivors at 35,
5.01753e+006
)
Units: **undefined**

(08) Age 35 to 39= INTEG (
Survivors at 35-Deaths 35 to 39-Survivors at 40,
4.04124e+006
)
Units: **undefined**

(09) Age 40 to 44= INTEG (
Survivors at 40-Deaths 40 to 44-Survivors at 45,
3.33605e+006
)
Units: **undefined**

(10) Age 45 to 49= INTEG (
Survivors at 45-Deaths 45 to 49-Survivors at 50,
2.74595e+006
)
Units: **undefined**

(11) Age 5 to 9= INTEG (
Survivors at 5-Deaths 5 to 9-Survivors at 10,
1.0111e+007
)
Units: **undefined**

(12) Age 50 and up= INTEG (
Survivors at 50-Deaths 50 and up,
7.87909e+006)
Units: **undefined**

(13) ASMP 15 to 19=
0.022
Units: **undefined**

(14) ASMR 0 to 4=
0.135
Units: **undefined**

(15) ASMR 10 to 14=
0.027
Units: **undefined**

(16) ASMR 20 to 24=
0.03
Units: **undefined**

(17) ASMR 25 to 29=
0.043
Units: **undefined**

(18) ASMR 30 to 34=
0.066
Units: **undefined** [0,1,0.001]

(19) ASMR 35 to 39=
0.076
Units: **undefined** [0,1,0.001]

(20) ASMR 40 to 44=
0.073
Units: **undefined** [0,1,0.001]

(21) ASMR 45 to 49=
0.069
Units: **undefined** [0,1,0.001]

(22) ASMR 5 to 9=
0.089
Units: **undefined**

This is an input for the country/slider.

(23) ASMR 50 and up=
0.13
Units: **undefined** [0,1,0.001]
Almost doubles the western death rate. At the beginning of the model run, a 50 year old would expect to live about 18 more years

(24) Birth Spacing Factor=
2.8
Units: **undefined** [1,25,0.1]
Factor converts desired family size to a desired number of births in an average five year period. It increases as women delay their first child and increase the intervals between children.

(25) Births 15 to 19=
Desired BR*Age 15 to 19*0.165
Units: **undefined**
.005 is the age specific birth rate for sweden

(26) Births 20 to 24=
Desired BR*Age 20 to 24*0.265
Units: **undefined**

(27) Births 25 to 29=
Desired BR*Age 25 to 29*0.289
Units: **undefined**

(28) Births 30 to 34=
Desired BR*Age 30 to 34*0.243
Units: **undefined**

(29) Births 35 to 39=
Desired BR*Age 35 to 39*0.167
Units: **undefined**

(30) Births 40 to 44=
Desired BR * Age 40 to 44 * 0.079
Units: **undefined**

(31) Births 45 to 49=
Desired BR*Age 45 to 49*0.037
Units: **undefined**

(32) Daughter to Mother ratio=
Daughters/Moms
Units: **undefined**
A proxy for the survival rate ... 23 year olds look at how many siblings they and others their age have and get a sense of how many more children they need to have

(33) Daughters=
Age 10 to 14+Age 15 to 19+Age 20 to 24+Age 25 to 29
Units: **undefined**

(34) Deaths 0 to 4=

Age 0 to 4*DR 0 to 4
Units: **undefined**

(35) Deaths 10 to 14=
Age 10 to 14*DR 10 to 14
Units: **undefined**

(36) Deaths 15 to 19=
Age 15 to 19*DR 15 to 19
Units: **undefined**

(37) Deaths 20 to 24=
Age 20 to 24*DR 20 to 24
Units: **undefined**

(38) Deaths 25 to 29=
Age 25 to 29*DR 25 to 29
Units: **undefined**

(39) Deaths 30 to 34=
Age 30 to 34*DR 30 to 34
Units: **undefined**

(40) Deaths 35 to 39=
Age 35 to 39*DR 35 to 39
Units: **undefined**

(41) Deaths 40 to 44=
Age 40 to 44*DR 40 to 44
Units: **undefined**

(42) Deaths 45 to 49=
Age 45 to 49*DR 45 to 49
Units: **undefined**

(43) Deaths 5 to 9=
DR 5 to 9*Age 5 to 9
Units: **undefined**

(44) Deaths 50 and up=
Age 50 and up*DR 50 and up
Units: **undefined**

(45) Desired BR=
Desired family size/Birth Spacing Factor
Units: **undefined**
the fuzzy number that is culturally derived.

(46) Desired family size= INTEG (
Net change,
10)
Units: **undefined**

(47) DR 0 to 4=
General Mortality factor*ASMR 0 to 4 + 0.006
Units: **undefined**
The .006 is based on the US infant mortality rate (6.06 per 1000)

(48) DR 10 to 14=
ASMR 10 to 14*General Mortality factor+0.0006
Units: **undefined**
.0006 is the ASDR for the US (lowest ASDR of a western country)

(49) DR 15 to 19=
General Mortality factor*ASMP 15 to 19+0.004
Units: **undefined**
.0040 is the ASDR for the US (lowest ASDR of a western country)

(50) DR 20 to 24=
General Mortality factor*ASMR 20 to 24+0.004
Units: **undefined**
.0040 is the ASDR for the US (lowest ASDR of a western country)

(51) DR 25 to 29=
General Mortality factor*ASMR 25 to 29+0.004
Units: **undefined**
.0040 is the ASDR for the US (lowest ASDR of a western country)

(52) DR 30 to 34=
General Mortality factor*ASMR 30 to 34+0.004
Units: **undefined** [0,1,0.001]
.0040 is the ASDR for the US (lowest ASDR of a western country)

(53) DR 35 to 39=
General Mortality factor*ASMR 35 to 39+0.008
Units: **undefined**
.0080 is the ASDR for the US (lowest ASDR of a western country)

(54) DR 40 to 44=
General Mortality factor*ASMR 40 to 44+0.008
Units: **undefined**
.0080 is the ASDR for the US (lowest ASDR of a western country)

(55) DR 45 to 49=
General Mortality factor*ASMR 45 to 49+0.0119
Units: **undefined**
.0119 is the ASDR for the US (lowest ASDR of a western country)

(56) DR 5 to 9=
ASMR 5 to 9*General Mortality factor+0.0005
Units: **undefined**
.0005 is the ASDR for the US (lowest ASDR of a western country)

(57) DR 50 and up=
General Mortality factor*ASMR 50 and up+0.17
Units: **undefined**
Set arbitrarily at 17% of the total over 50 population every 5 years; remember that this includes 95 year olds as well as 50 year olds! 17% should roughly correspond to a life expectancy at age 50 of 30 more years in developed counties.

(58) FINAL TIME = 40
Units: Year
The final time for the simulation.

(59) General Mortality factor= INTEG (
-Mortality reduction,
1)
Units: **undefined** [0,1]
Improving health reduces the general death rate.

(60) INITIAL TIME = 1
Units: Year
The initial time for the simulation.

(61) Moms=
Age 30 to 34+Age 35 to 39+Age 40 to 44+Age 45 to 49
Units: **undefined**

(62) Mortality reduction=
General Mortality factor*Mortality reduction rate
Units: **undefined**

(63) Mortality reduction rate=
0.08
Units: **undefined** [0,0.5,0.01]

(64) Net change=
IF THEN ELSE (Daughter to Mother ratio > Threshold :AND: Desired family size > 2, -Desired family size*Rate of change, IF THEN ELSE

(Daughter to Mother ratio < 1 , 0.1 , 0))
Units: **undefined**

(65) Rate of change=
0.04
Units: **undefined** [0,0.25,0.01]

(66) SAVEPER =
TIME STEP
Units: Year [0,?]
The frequency with which output is stored.

(67) Survivors at 10=
Age 5 to 9*(1-DR 5 to 9)
Units: **undefined**

(68) Survivors at 15=
Age 10 to 14*(1-DR 10 to 14)
Units: **undefined**

(69) Survivors at 20=
Age 15 to 19*(1-DR 15 to 19)
Units: **undefined**

(70) Survivors at 25=
Age 20 to 24*(1-DR 20 to 24)
Units: **undefined**

(71) Survivors at 30=
Age 25 to 29*(1-DR 25 to 29)

Units: **undefined**

(72) Survivors at 35=
Age 30 to 34*(1-DR 30 to 34)
Units: **undefined**

(73) Survivors at 40=
Age 35 to 39*(1-DR 35 to 39)
Units: **undefined**

(74) Survivors at 45=
Age 40 to 44*(1-DR 40 to 44)
Units: **undefined**

(75) Survivors at 5=
Age 0 to 4*(1-DR 0 to 4)
Units: **undefined**

(76) Survivors at 50=
Age 45 to 49*(1-DR 45 to 49)
Units: **undefined**

(77) Threshold=
1.1
Units: **undefined** [1,2.1,0.01]

(78) TIME STEP = 1
Units: Year [0,?]
The time step for the simulation.

(79) Total pop=
"30 and up"+Under 30
Units: **undefined**

(80) Under 30=
Age 0 to 4+Age 5 to 9+Daughters
Units: **undefined**

EDUCATION MODEL EQUATIONS

(01) "30 and up"=
Moms+Age 50 and up
Units: **undefined**

(02) Age 0 to 4= INTEG (
Births 15 to 19+Births 20 to 24+Births 25 to 29+Births 30 to 34+Births 35 to 39
+Births 40 to 44+Births 45 to 49-Deaths 0 to 4-Survivors at 5,
1.15249e+007
)
Units: **undefined**

(03) Age 10 to 14= INTEG (
Survivors at 10-Deaths 10 to 14-Survivors at 15,
9.02656e+006
)
Units: **undefined**

(04) Age 15 to 19= INTEG (
Survivors at 15-Deaths 15 to 19-Survivors at 20,
7.95236e+006
)
Units: **undefined**

(05) Age 20 to 24= INTEG (
Survivors at 20-Deaths 20 to 24-Survivors at 25,
6.94984e+006
)
Units: **undefined**

(06) Age 25 to 29= INTEG (
Survivors at 25-Deaths 25 to 29-Survivors at 30,
6.03997e+006
)
Units: **undefined**

(07) Age 30 to 34= INTEG (
Survivors at 30-Deaths 30 to 34-Survivors at 35,
5.01753e+006
)
Units: **undefined**

(08) Age 35 to 39= INTEG (
Survivors at 35-Deaths 35 to 39-Survivors at 40,
4.04124e+006
)
Units: **undefined**

(09) Age 40 to 44= INTEG (
Survivors at 40-Deaths 40 to 44-Survivors at 45,
3.33605e+006
)
Units: **undefined**

(10) Age 45 to 49= INTEG (
Survivors at 45-Deaths 45 to 49-Survivors at 50,
2.74595e+006
)
Units: **undefined**

(11) Age 5 to 9= INTEG (
Survivors at 5-Deaths 5 to 9-Survivors at 10,
1.0111e+007
)
Units: **undefined**

(12) Age 50 and up= INTEG (
Survivors at 50-Deaths 50 and up,
7.87909e+006)
Units: **undefined**

(13) ASMP 15 to 19=
0.022
Units: **undefined**

(14) ASMR 0 to 4=
0.135
Units: **undefined**

(15) ASMR 10 to 14=
0.027
Units: **undefined**

(16) ASMR 20 to 24=
0.03
Units: **undefined**

(17) ASMR 25 to 29=
0.043
Units: **undefined**

(18) ASMR 30 to 34=
0.066
Units: **undefined** [0,1,0.001]

(19) ASMR 35 to 39=
0.076
Units: **undefined** [0,1,0.001]

(20) ASMR 40 to 44=
0.073
Units: **undefined** [0,1,0.001]

(21) ASMR 45 to 49=
0.069
Units: **undefined** [0,1,0.001]

(22) ASMR 5 to 9=
0.089
Units: **undefined**
This is an input for the country/slider.

(23) ASMR 50 and up=
0.13
Units: **undefined** [0,1,0.001]
Almost doubles the western death rate. At the beginning of the model run, a 50 year old would expect to live about 18 more years

(24) Birth Spacing Factor=
2.8
Units: **undefined** [1,25,0.1]
Factor converts desired family size to a desired number of births in an average five year period. It increases as women delay their first child and increase the intervals between children.

(25) Births 15 to 19=
Desired BR*Age 15 to 19*0.165
Units: **undefined**
.005 is the age specific birth rate for sweden

(26) Births 20 to 24=

Desired BR*Age 20 to 24*0.265
Units: **undefined**

(27) Births 25 to 29=
Desired BR*Age 25 to 29*0.289
Units: **undefined**

(28) Births 30 to 34=
Desired BR*Age 30 to 34*0.243
Units: **undefined**

(29) Births 35 to 39=
Desired BR*Age 35 to 39*0.167
Units: **undefined**

(30) Births 40 to 44=
Desired BR * Age 40 to 44 * 0.079
Units: **undefined**

(31) Births 45 to 49=
Desired BR*Age 45 to 49*0.037
Units: **undefined**

(32) Daughter to Mother ratio=
Daughters/Moms
Units: **undefined**
A proxy for the survival rate ... 23 year olds look at how many siblings they and others their age have and get a sense of how many more children they need to have

(33) Daughters=
Age 10 to 14+Age 15 to 19+Age 20 to 24+Age 25 to 29
Units: **undefined**

(34) Deaths 0 to 4=
Age 0 to 4*DR 0 to 4
Units: **undefined**

(35) Deaths 10 to 14=
Age 10 to 14*DR 10 to 14
Units: **undefined**

(36) Deaths 15 to 19=
Age 15 to 19*DR 15 to 19
Units: **undefined**

(37) Deaths 20 to 24=
Age 20 to 24*DR 20 to 24
Units: **undefined**

(38) Deaths 25 to 29=
Age 25 to 29*DR 25 to 29
Units: **undefined**

(39) Deaths 30 to 34=
Age 30 to 34*DR 30 to 34
Units: **undefined**

(40) Deaths 35 to 39=
Age 35 to 39*DR 35 to 39
Units: **undefined**

(41) Deaths 40 to 44=
Age 40 to 44*DR 40 to 44
Units: **undefined**

(42) Deaths 45 to 49=
Age 45 to 49*DR 45 to 49
Units: **undefined**

(43) Deaths 5 to 9=
DR 5 to 9*Age 5 to 9
Units: **undefined**

(44) Deaths 50 and up=
Age 50 and up*DR 50 and up
Units: **undefined**

(45) Desired BR=
Desired family size/Birth Spacing Factor+(Literacy Factor*literacy multiplier
)
Units: **undefined**
the fuzzy number that is culturally derived.

(46) Desired family size= INTEG (
Net change,
10)
Units: **undefined**

(47) DR 0 to 4=
General Mortality factor*ASMR 0 to 4 + 0.006-Literacy Factor
Units: **undefined**
The .006 is based on the US infant mortality rate (6.06 per 1000)

(48) DR 10 to 14=
ASMR 10 to 14*General Mortality factor+0.0006
Units: **undefined**
.0006 is the ASDR for the US (lowest ASDR of a western country)

(49) DR 15 to 19=
General Mortality factor*ASMP 15 to 19+0.004
Units: **undefined**
.0040 is the ASDR for the US (lowest ASDR of a western country)

(50) DR 20 to 24=
General Mortality factor*ASMR 20 to 24+0.004
Units: **undefined**
.0040 is the ASDR for the US (lowest ASDR of a western country)

(51) DR 25 to 29=
General Mortality factor*ASMR 25 to 29+0.004
Units: **undefined**
.0040 is the ASDR for the US (lowest ASDR of a western country)

(52) DR 30 to 34=
General Mortality factor*ASMR 30 to 34+0.004
Units: **undefined** [0,1,0.001]
.0040 is the ASDR for the US (lowest ASDR of a western country)

(53) DR 35 to 39=
General Mortality factor*ASMR 35 to 39+0.008
Units: **undefined**
.0080 is the ASDR for the US (lowest ASDR of a western country)

(54) DR 40 to 44=
General Mortality factor*ASMR 40 to 44+0.008
Units: **undefined**
.0080 is the ASDR for the US (lowest ASDR of a western country)

(55) DR 45 to 49=
General Mortality factor*ASMR 45 to 49+0.0119
Units: **undefined**
.0119 is the ASDR for the US (lowest ASDR of a western country)

(56) DR 5 to 9=
ASMR 5 to 9*General Mortality factor+0.0005
Units: **undefined**
.0005 is the ASDR for the US (lowest ASDR of a western country)

(57) DR 50 and up=
General Mortality factor*ASMR 50 and up+0.17
Units: **undefined**
Set arbitrarily at 17% of the total over 50 population every 5 years; remember that this includes 95 year olds as well as 50 year olds! 17% should roughly correspond to a life expectancy at age 50 of 30 more years in developed counties.

(58) FINAL TIME = 40
Units: Year
The final time for the simulation.

(59) General Mortality factor= INTEG (
-Mortality reduction,
1)
Units: **undefined** [0,1]
Improving health reduces the general death rate.

(60) INITIAL TIME = 1
Units: Year
The initial time for the simulation.

(61) Literacy Factor=
0.025
Units: **undefined** [?,?,0.001]

(62) literacy multiplier=
-6
Units: **undefined**

(63) Moms=
Age 30 to 34+Age 35 to 39+Age 40 to 44+Age 45 to 49

Units: **undefined**

(64) Mortality reduction=
General Mortality factor*Mortality reduction rate
Units: **undefined**

(65) Mortality reduction rate=
0.08+Literacy Factor
Units: **undefined** [0,0.5,0.01]

(66) Net change=
IF THEN ELSE (Daughter to Mother ratio > Threshold :AND: Desired family size > 2, -Desired family size*Rate of change
, IF THEN ELSE

(Daughter to Mother ratio < 1 , 0.1 , 0))
Units: **undefined**

(67) Rate of change=
0.04
Units: **undefined** [0,0.25,0.01]

(68) SAVEPER =
TIME STEP
Units: Year [0,?]
The frequency with which output is stored.

(69) Survivors at 10=
Age 5 to 9*(1-DR 5 to 9)
Units: **undefined**

(70) Survivors at 15=
Age 10 to 14*(1-DR 10 to 14)
Units: **undefined**

(71) Survivors at 20=
Age 15 to 19*(1-DR 15 to 19)
Units: **undefined**

(72) Survivors at 25=
Age 20 to 24*(1-DR 20 to 24)
Units: **undefined**

(73) Survivors at 30=
Age 25 to 29*(1-DR 25 to 29)
Units: **undefined**

(74) Survivors at 35=
Age 30 to 34*(1-DR 30 to 34)
Units: **undefined**

(75) Survivors at 40=
Age 35 to 39*(1-DR 35 to 39)
Units: **undefined**

(76) Survivors at 45=
Age 40 to 44*(1-DR 40 to 44)

Units: **undefined**

(77) Survivors at 5=
Age 0 to 4*(1-DR 0 to 4)
Units: **undefined**

(78) Survivors at 50=
Age 45 to 49*(1-DR 45 to 49)
Units: **undefined**

(79) Threshold=
1.1
Units: **undefined** [1,2.1,0.01]

(80) TIME STEP = 1
Units: Year [0,?]
The time step for the simulation.

(81) Total pop=
"30 and up"+Under 30
Units: **undefined**

(82) Under 30=
Age 0 to 4+Age 5 to 9+Daughters
Units: **undefined**

APPENDIX 1: DATA

AGE SPECIFIC BIRTH RATES

Country or Area	Subgroup	Year	Source	Unit	2000 - 2005	1995 - 2000
Guatemala	Female 15-19 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	115.4	121.1
Guatemala	Female 20-24 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	238.1	253.4
Guatemala	Female 25-29 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	218.2	236.5
Guatemala	Female 30-34 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	174	191.8
Guatemala	Female 35-39 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	115.9	130.1
Guatemala	Female 40-44 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	48.8	55.8
Guatemala	Female 45-49 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	9.6	11.4
Mexico	Female 15-19 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	70	77.8
Mexico	Female 20-24 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	129.5	139.5
Mexico	Female 25-29 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	131	143.6
Mexico	Female 30-34 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	87.7	99.1
Mexico	Female 35-39 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	48.9	57.7
Mexico	Female 40-44 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	10.7	13.4
Mexico	Female 45-49 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	2.3	3
Nigeria	Female 15-19 yr	2000 -	UNPD_World Population Prospects_2006 (International	Births per 1,000	153.3	165.9

		2005	estimate)	women		
Nigeria	Female 20-24 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	241.5	265.6
Nigeria	Female 25-29 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	281.6	289.3
Nigeria	Female 30-34 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	244.3	243.8
Nigeria	Female 35-39 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	165.3	167.6
Nigeria	Female 40-44 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	68.2	79.4
Nigeria	Female 45-49 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	14.8	37.5
Sweden	Female 15-19 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	4.6	5.1
Sweden	Female 20-24 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	41.6	46.8
Sweden	Female 25-29 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	102.8	106.3
Sweden	Female 30-34 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	117.9	98.5
Sweden	Female 35-39 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	55	44.7
Sweden	Female 40-44 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	11.5	9.1
Sweden	Female 45-49 yr	2000 - 2005	UNPD_World Population Prospects_2006 (International estimate)	Births per 1,000 women	0.6	0.4

INFANT MORTALITY

Country or Area	Year(s)	Variant	Value
Guatemala	2000-2005	Estimate variant	33
Mexico	2000-2005	Estimate variant	18.02

Nigeria	2000-2005	Estimate variant	109.19
Sweden	2000-2005	Estimate variant	3.098

Source:
http://data.un.org/Data.aspx?q=mortality+rate+datamart%5bGenderStat%2cPopDiv%5d&d=PopDiv&f=variableID%3a76

UNDER 5 MORTALITY RATE

Country or Area	Subgroup	Year	Source	Unit	Value
Guatemala	Female 0-4 yr	2000-2005	UNPD_World Population Prospects_2006 (International estimate)	Deaths per 1000 live births	42.3
Mexico	Female 0-4 yr	2000-2005	UNPD_World Population Prospects_2006 (International estimate)	Deaths per 1000 live births	21.8
Nigeria	Female 0-4 yr	2000-2005	UNPD_World Population Prospects_2006 (International estimate)	Deaths per 1000 live births	194.2
Sweden	Female 0-4 yr	2000-2005	UNPD_World Population Prospects_2006 (International estimate)	Deaths per 1000 live births	3.7

Source:
http://data.un.org/Data.aspx?q=mortality+rate+datamart%5bGenderStat%2cPopDiv%5d&d=GenderStat&f=inID%3a42

MORTALITY PROBABILITY RATE (NOT USED)

Country or Area	Year(s)	GENDER	Value
Guatemala	2007	Female	161
Guatemala	2000	Female	178
Mexico	2007	Female	89
Mexico	2000	Female	99
Nigeria	2007	Female	389
Nigeria	2000	Female	395
Sweden	2007	Female	48
Sweden	2000	Female	56

CRUDE DEATH RATE (NOT USED)

Country or Area	Year(s)	Variant	Value
Guatemala	2000-2005	Estimate variant	6.051
Mexico	2000-2005	Estimate variant	4.73

Nigeria	2000-2005	Estimate variant	17.389
Sweden	2000-2005	Estimate variant	10.39

Source: http://data.un.org/Data.aspx?q=crude+death+rate&d=PopDiv&f=variableID%3a65

NIGERIA AGE SPECIFIC DEATH RATE (CALCULATED)

Nigeria					
	2005 Data	**2010 Data**		**Death**	**Death**
Age Range	**Female Population**	**Female Population**	**Deaths**	**Rate***	**Rate**
Total	67,377,625	74,624,483			
0-4	11,014,353	11,524,888			
5-9	9,271,853	10,111,011	903,342	8.934	0.0893424
10-14	8,125,100	9,026,559	245,294	2.717	0.0271747
15-19	7,155,696	7,952,360	172,740	2.172	0.0217219
20-24	6,301,295	6,949,841	205,855	2.962	0.0296201
25-29	5,349,039	6,039,974	261,321	4.327	0.0432653
30-34	4,348,546	5,017,530	331,509	6.607	0.0660702
35-39	3,579,924	4,041,236	307,310	7.604	0.0760436
40-44	2,936,564	3,336,053	243,871	7.310	0.0731017
45-49	2,370,737	2,745,945	190,619	6.942	0.0694184
50-54	1,965,926	2,208,524	162,213	7.345	0.0734486
55-59	1,630,003	1,802,171	163,755	9.087	0.0908654
60-64	1,264,188	1,448,017	181,986	12.568	0.1256795
65-69	914,148	1,063,115	201,073	18.914	0.1891357
70-74	603,637	702,203	211,945	30.183	0.3018287
75-79	341,903	403,966	199,671	49.428	0.4942767
80-84	150,560	183,167	158,736	86.662	0.866619
85-89	45,031	56,211	94,349	167.848	1.6784793
90-94	8,254	10,558	34,473	326.511	3.265107
95-99	825	1,094	7,160	654.479	6.5447898
100+	43	60	765	1275.000	12.75
TOTAL 50+				239.820	2.3982027

SWEDEN AGE SPECIFIC MORTALITY RATE (CALCULATED)

Sweden					
	2005 Data	**2010 Data**		**Death**	**Death**
Age Range	**Female Population**	**Female Population**	**Deaths**	**Rate***	**Rate**
Total	4,542,962	4,576,420			
0-4	226,660	224,396			

5-9	227,412	229,402	-2,742	-1.195	- 0.0119528
10-14	293,549	230,661	-3,249	-1.409	- 0.0140856
15-19	294,819	298,261	-4,712	-1.580	- 0.0157982
20-24	257,803	302,358	-7,539	-2.493	-0.024934
25-29	261,889	266,084	-8,281	-3.112	-0.0311218
30-34	292,095	266,898	-5,009	-1.877	- 0.0187675
35-39	307,563	294,277	-2,182	-0.741	- 0.0074148
40-44	313,932	308,377	-814	-0.264	- 0.0026396
45-49	286,405	313,369	563	0.180	0.0017966
50-54	286,266	284,446	1,959	0.689	0.0068871
55-59	309,522	282,774	3,492	1.235	0.0123491
60-64	294,579	303,637	5,885	1.938	0.0193817
65-69	219,147	285,519	9,060	3.173	0.0317317
70-74	186,109	206,220	12,927	6.269	0.0626855
75-79	176,517	167,282	18,827	11.255	0.1125465
80-84	154,644	144,941	31,576	21.785	0.2178542
85-89	103,388	105,290	49,354	46.874	0.4687435
90-94	41,200	49,819	53,569	107.527	1.0752725
95-99	8,702	11,204	29,996	267.726	2.6772581
100+	761	1,205	7,497	622.158	6.2215768
TOTAL 50+				99.148	0.9914806

US AGE SPECIFIC MORTALITY RATE (PROVIDED BY DR. KAUFFMAN)

Age	Survivor Rate	Total Pop	5 year Survivor rates	Death Rate
0	1	100000		
1	0.994	99400		
2	0.9995	99350		
3	0.9996	99311		
4	0.9997	**99281**	0.992807667	0.00719233
5	0.9998	99261		
6	0.9998	99241		
7	0.9999	99231		
8	0.9999	99221		
9	0.9999	**99211**	0.99950009	0.00049991
10	0.9999	99201		
11	0.9999	99191		
12	0.9999	99182		
13	0.9998	99162		
14	0.9998	**99142**	0.99940013	0.00059987
15	0.999	99043		
16	0.999	98944		
17	0.999	98845		

18	0.999	98746		
19	0.999	**98647**	0.996005996	0.003994
20	0.999	98548		
21	0.999	98450		
22	0.999	98351		
23	0.999	98253		
24	0.999	**98155**	0.996005996	0.003994
25	0.999	98057		
26	0.999	97959		
27	0.999	97861		
28	0.999	97763		
29	0.999	**97665**	0.996005996	0.003994
30	0.999	97567		
31	0.999	97470		
32	0.999	97372		
33	0.999	97275		
34	0.999	**97178**	0.996005996	0.003994
35	0.998	96983		
36	0.998	96789		
37	0.998	96596		
38	0.998	96403		
39	0.998	**96210**	0.992023968	0.00797603
40	0.998	96017		
41	0.998	95825		
42	0.998	95634		
43	0.998	95442		
44	0.998	**95252**	0.992023968	0.00797603
45	0.997	94966		
46	0.997	94681		
47	0.997	94397		
48	0.997	94114		
49	0.997	**93831**	0.988053892	0.01194611
50	0.996	93456		
51	0.996	93082		
52	0.996	92710		
53	0.995	92246		
54	0.994	**91693**	0.981133584	0.01886642
55	0.994	91143		
56	0.993	90505		
57	0.993	89871		
58	0.992	89152		
59	0.992	**88439**	0.970335323	0.02966468

Source: US Census

APPENDIX 2: THE ORIGINAL ARTICLE

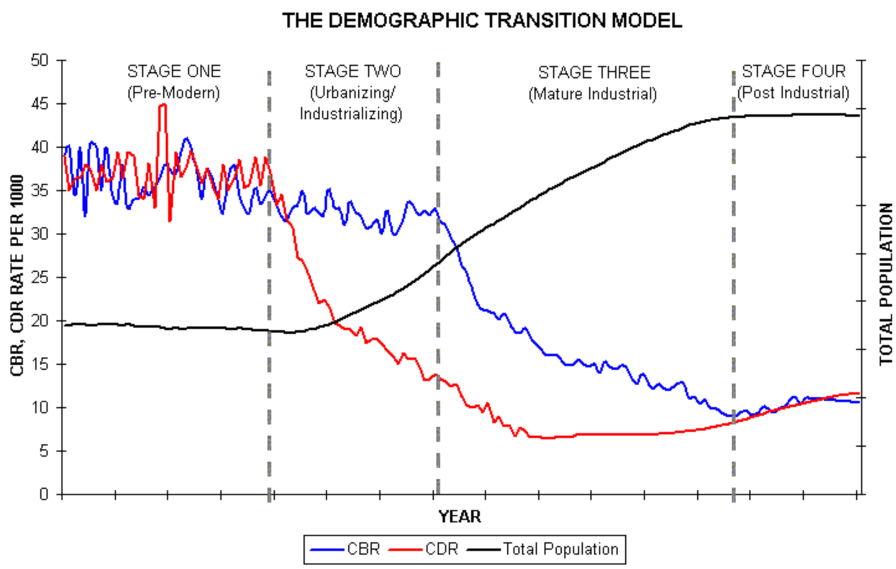
The "Demographic Transition" is a model that describes population change over time. It is based on an interpretation begun in 1929 by the American demographer Warren Thompson, of the observed changes, or transitions, in birth and death rates in industrialized societies over the past two hundred years or so.

By "model" we mean that it is an idealized, composite picture of population change in these countries. The model is a generalization that applies to these countries as a group and may not accurately describe all individual cases. Whether or not it applies to less developed societies today remains to be seen.

Link: http://www.marathon.uwc.edu/geography/demotrans/demtran.htm

Before proceeding you should review some demographic terminology **or be sure to follow the links given below as the terms arise**.

The model is illustrated below:

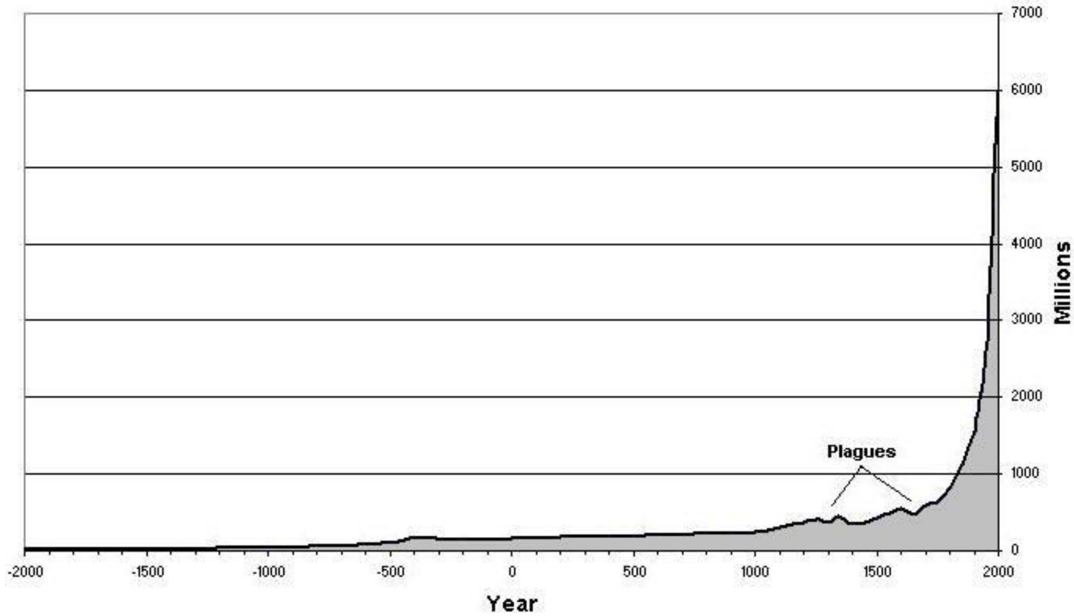


As shown, there are four stages of transition. They will be described first in terms of a typical fully developed country today, such as The United States or Canada, the countries of Europe, or similar societies elsewhere (e.g. Japan, Australia etc.).

STAGE ONE is associated with pre Modern times, and is characterized by a balance between birth rates and death rates. This situation was true of all human populations up until the late 18th.C. when the balance was broken in western Europe.

Note that, in this stage, birth and death rates are both very high (30-50 per thousand). Their approximate balance results in only very slow population growth. Over much of pre-history, at least since the "Agricultural Revolution" 10,000 years ago, population growth was extremely slow. Growth rates would

have been less than 0.05%, resulting in long doubling times of the order of 1-5,000 yrs.



HIGHLIGHTS IN WORLD POPULATION GROWTH

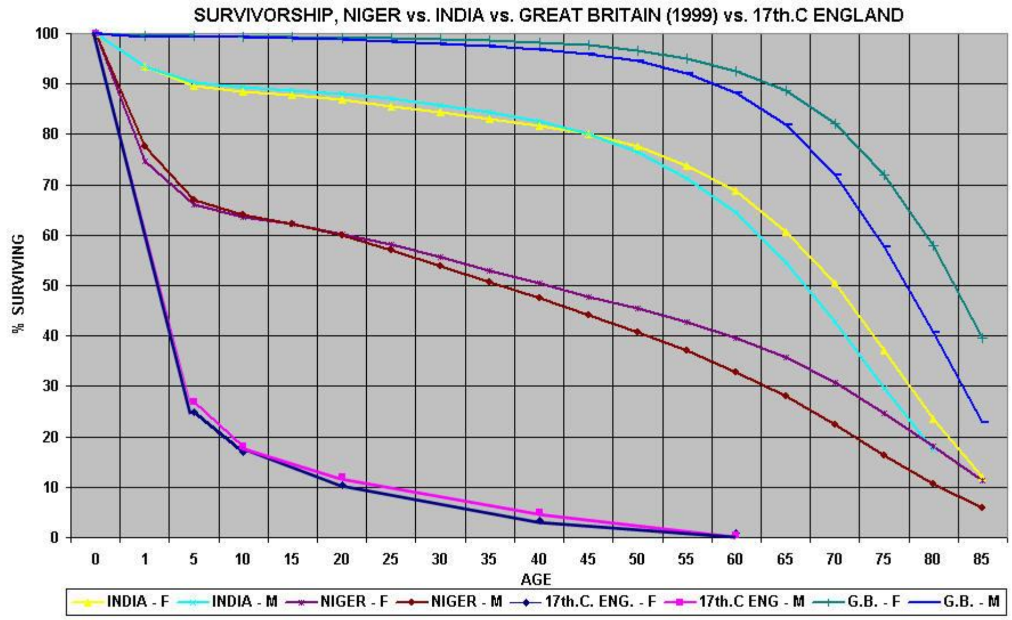
1 billion in 1804	3 billion in 1960 (33 years later)	5 billion in 1987 (13 years later)
2 billion in 1927 (123 years later)	4 billion in 1974 (14 years later)	6 billion in 1999 (12 years later)

Given its characteristics, Stage One is sometimes referred to as the "High Stationary Stage" of population growth ("high" birth and death rates; "stationary" rates and "stationary" total population numbers).

Death rates were very high at all times in this stage for a number of reasons, including:

- Lack of knowledge of disease prevention and cure;
- occasional food shortages.

Spikes in the rate of death were caused by outbreaks of infectious diseases such as influenza, scarlet fever, or plague. However, on a daily basis, it was primarily the lack of clean drinking water and efficient sewage disposal, and poor food hygiene that created an environment in which only a minority of children survived childhood. Water and food borne diseases such as cholera, typhoid, typhus, dysentery, and diarrhea were common killers, as were TB, measles, diphtheria, and whooping cough. Today in the developed world, at least, these are now minority causes of death.

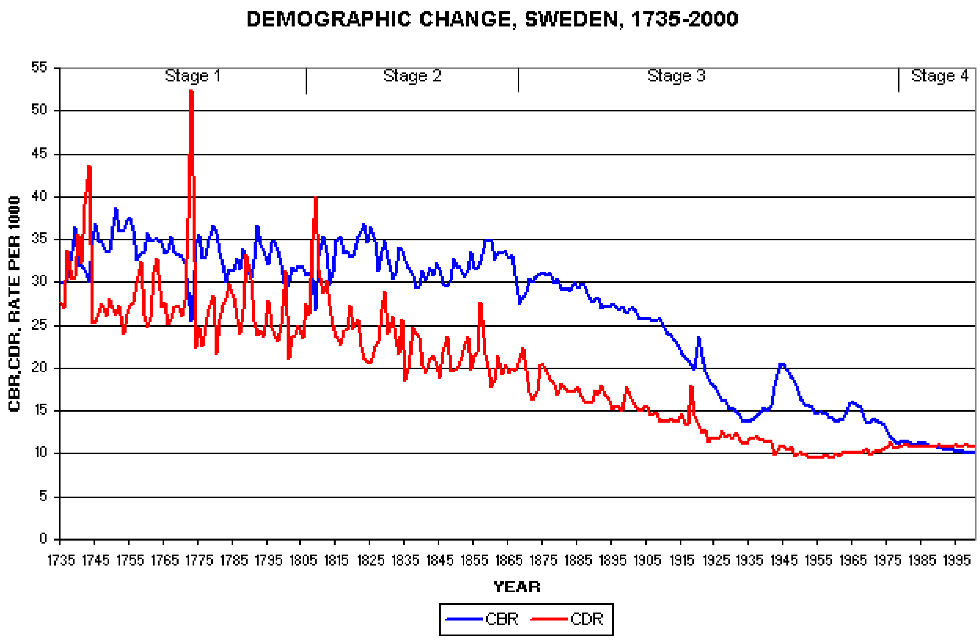


Survivorship curve: Survivorship curves keep track of the fate of any given birth cohort. They show the percent still living at a given age. Nowadays in the developed world few children die before reproduction. In Great Britain in 1999 only 1% of all children born alive died by the age of five (compared to 10% in India, and 35% in Niger). However, 300 years ago it was quite a different matter, as the graph above illustrates. In the City of York (England) in the 17th. Century, only 15% made it to the threshold of reproduction (15 yrs.). Only 10% remained alive by the age of twenty. With so few females living to reproduction, only a high fertility rate could maintain the population. Note that changes with economic development, as shown by Niger and India. Note also the impact of bias against females in India on their survival -- otherwise, India's curve in 1999 is very similar to Great Britain's for the late 19th. C. (not shown).

The high rate of birth (even higher if one were to adjust it for women of childbearing age) could be due any or all of the factors that are associated with high fertilityeven today in many less developed countries. With a high death rate among children, there would be little incentive in rural societies to control fertility except in the most unbearable of circumstances.

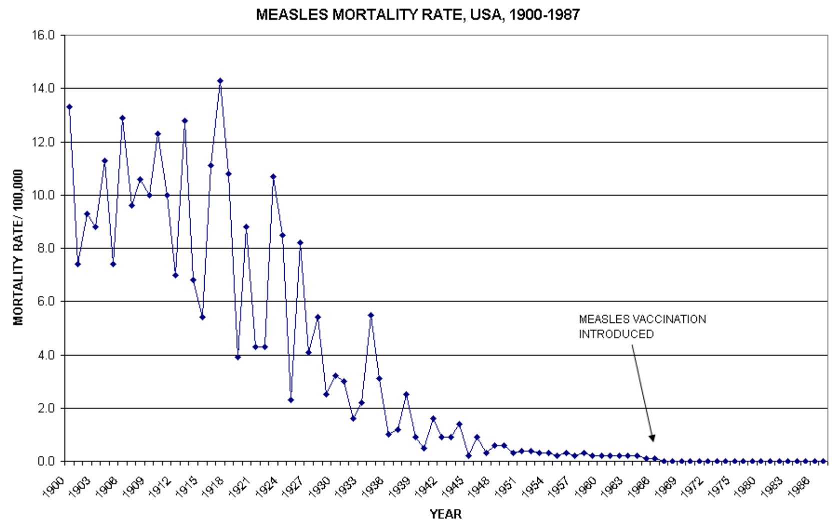
Stage One, then, characterizes all world regions up until the 17th.C. Some demographers sum up its character as a "Malthusian stalemate".

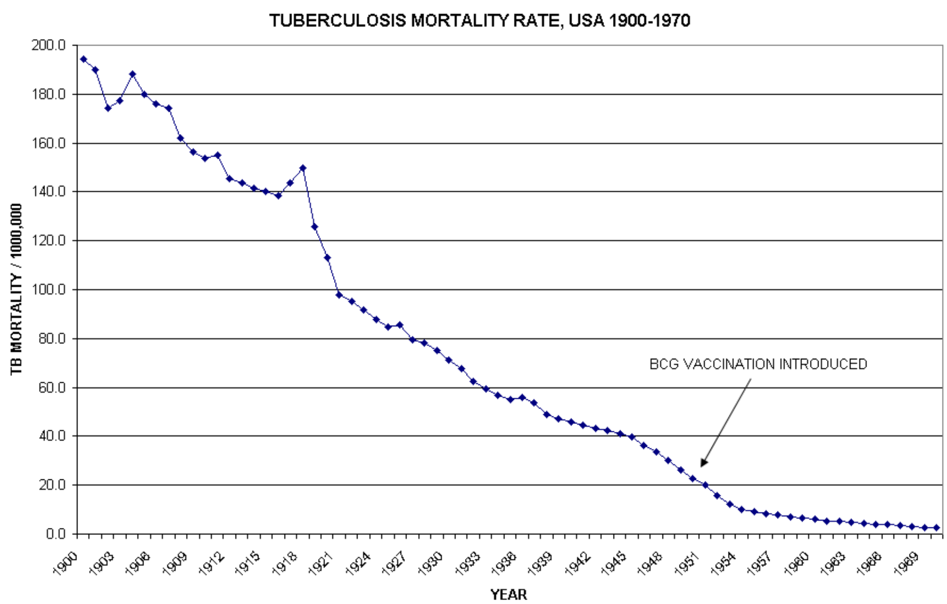
STAGE TWO sees a rise in population caused by a decline in the death rate while the birth rate remains high, or perhaps even rises slightly. The decline in the death rate in Europe began in the late 18th.C. in northwestern Europe and spread over the next 100 years to the south end east. Data from Sweden clearly show this stage (and two other stages following it):



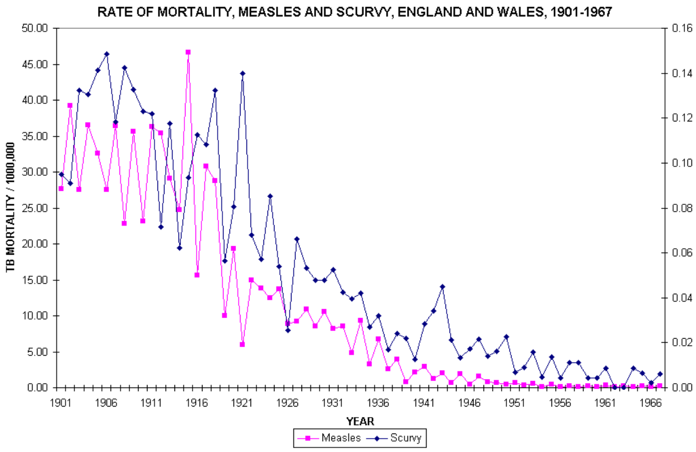
The decline in the death rate is due initially to two factors:

- First, improvements in food supply brought about by higher yields as agricultural practices were improved in the Agricultural Revolution of the 18th.C. These improvements included crop rotation, selective breeding, and seed drill technology. In England, the greater wealth this brought about enabled people to marry earlier, thus raising the birth rate slightly at the same time. Another food related factor was the introduction of the potato and maize (corn) from the Americas. These new crops increased the quantity of foodstuffs in the European diet, especially in northern Europe.
- Second, there were significant improvements in public health that reduced mortality, particularly in childhood. These are not so much medical breakthroughs (which did not come until the mid 20th.C.) as they are improvements in water supply, sewage, food handling, and general personal hygiene following on from growing scientific knowledge of the causes of disease. This is illustrated below for the case of measles and TB in the USA over the past 100 years. However, bear in mind that killer infectious diseases such as TB are airborne and not water borne, so public engineering works such as sewer and water supply cannot take all the credit. In fact, perhaps the most important factor here was increased female literacy allied with public health education programs in the late 19th. and early 20th. Centuries.

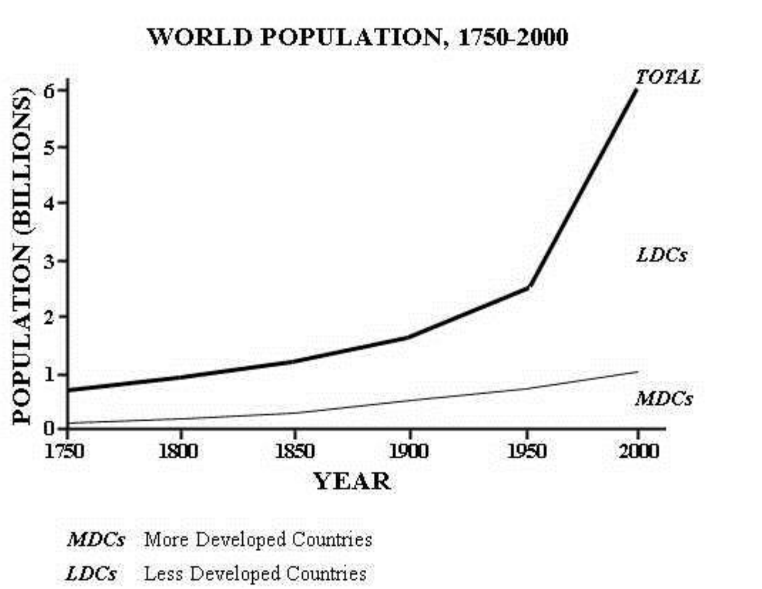


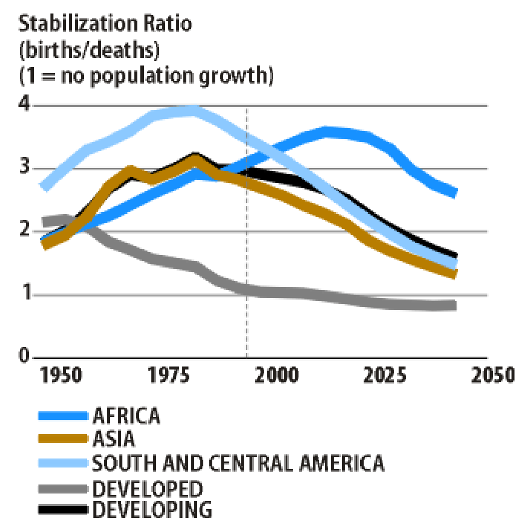


From the relationship between scurvy and measles in England and Wales (scurvy is caused by a dietary deficiency in vitamin C), one could surmise that general improvements in human wellbeing, an increase in public health awareness, and a decline in poverty was most at work in the decline of infectious diseases.



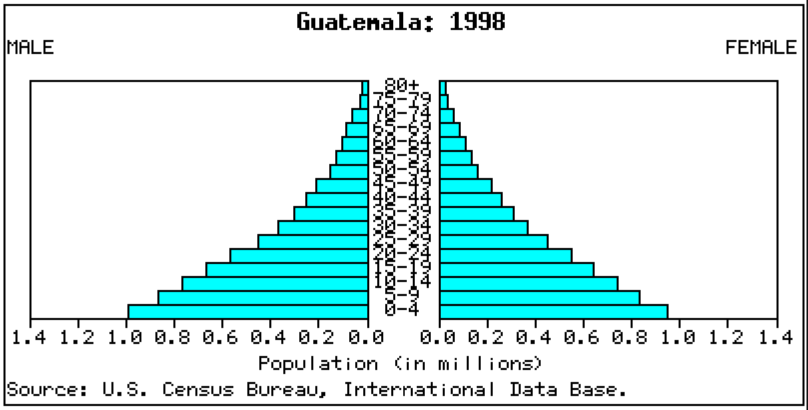
A consequence of the decline in mortality in Stage Two is an increasingly rapid rise in population growth (a "population explosion") as the gap between deaths and births grows wider. Note that this growth is not due to an increase in fertility (or birth rates) but to a decline in deaths. This change in population growth in northwestern Europe begins the population rise that has characterized the last two centuries, climaxing in the second half of the 20th.C. as less developed countries entered Stage Two (next two plots):





(Source: WRI)

Another characteristic of Stage Two of the demographic transition is a change in the age structure of the population. In Stage One the majority of death is concentrated in the first 5-10 years of life. Therefore, more than anything else, the decline in death rates in Stage Two entails the increasing survival of children. Hence, the age structure of the population becomes increasingly youthful. This trend is intensified as this increasing number of children enter into reproduction while maintaining the high fertility rate of their parents. The age structure of such a population is illustrated below by using an example from the Third World today:

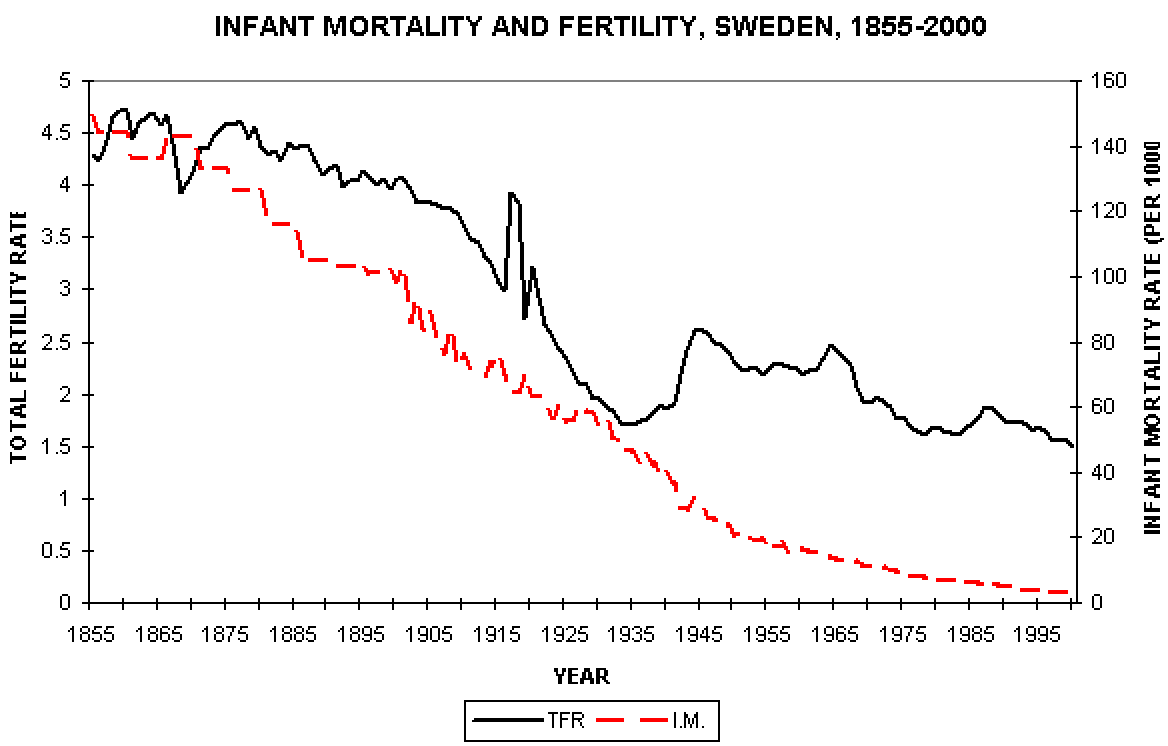


Demographic Indicators

Birth Rate: 36 per thousand
Total fertility rate: 4.8 births
Natural increase: 2.9% per year
1990-2000
Age structure: 43% under 15 yrs.age

STAGE THREE moves the population towards stability through a decline in the **birth rate**. This shift belies Malthus's belief that changes in the death rates were the primary cause of population change.

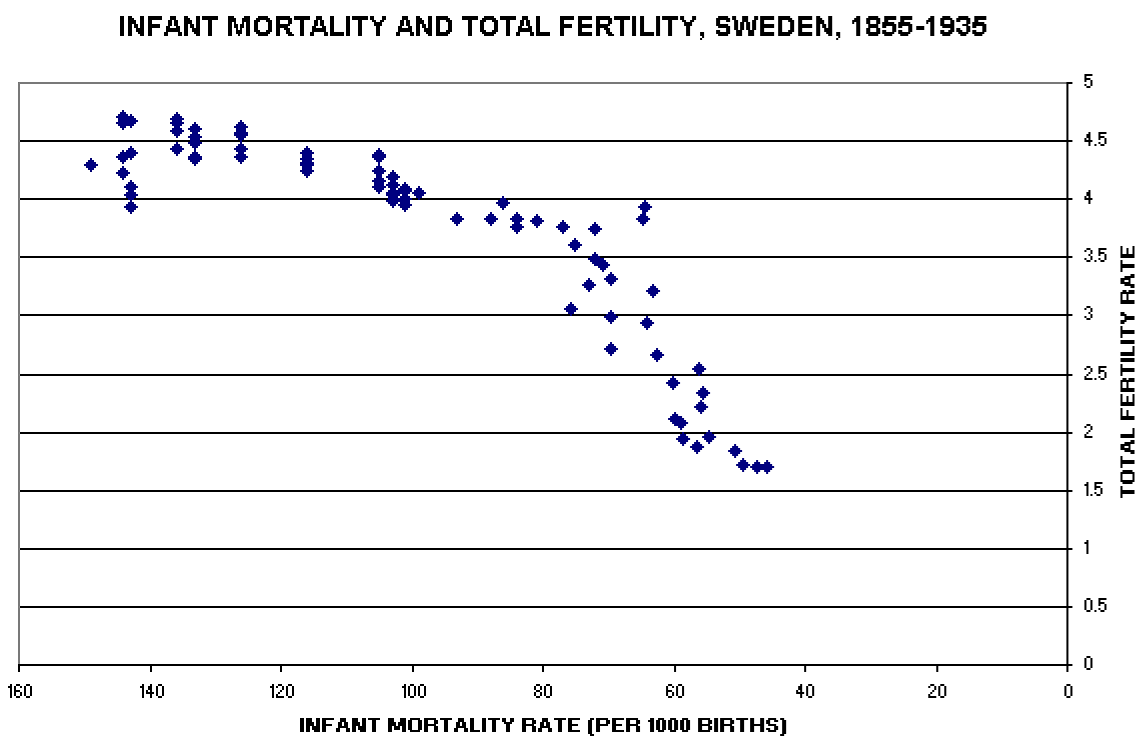
In general the decline in birth rates in developed countries began towards the end of the 19th.C. in northern Europe and followed the decline in death rates by several decades (see example of Sweden, in Stage Two above).



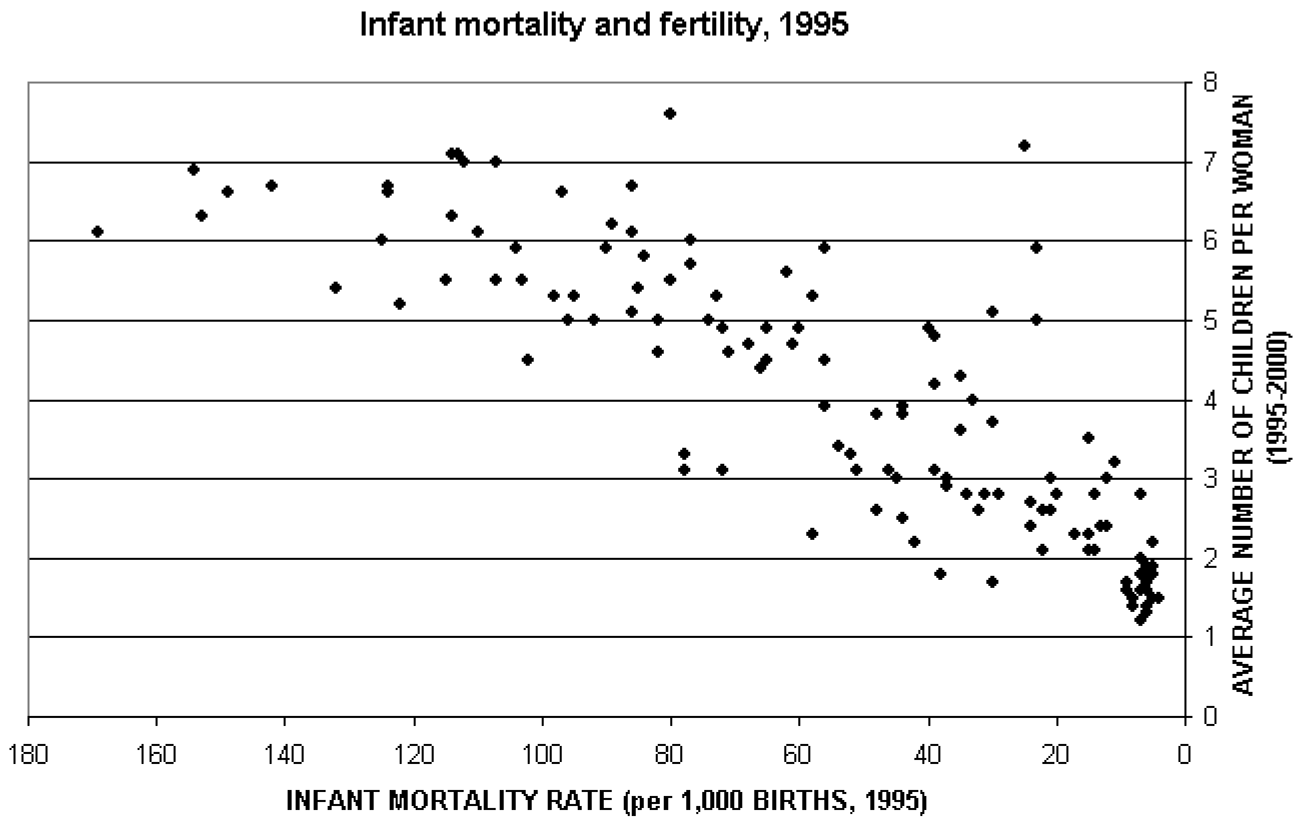
There are several factors contributing to this eventual decline, <u>although some of them remain speculative</u>:

- In rural areas continued decline in childhood death means that at some point parents realize they need not require so many children to be born to ensure a comfortable old age. As childhood death continues to fall parents can become increasingly confident that even fewer children will suffice.
- Increasing urbanization changes the traditional values placed upon fertility and the value of children in rural society. Urban living also raises the cost of dependent children to a nuclear family (education acts and child labor acts increased dependency through the late 1800s). People begin to assess more rationally just how many children they desire or need. Once traditional patterns of thinking are broken the decline is likely to accelerate.
- Increasing female literacy and employment lower the uncritical acceptance of childbearing and motherhood as measures of the status of women. Valuation of women beyond childbearing and motherhood becomes important. In addition, as women enter the work force their life extends beyond the family and the connections they make with other women serve to break their isolation and change their attitudes towards the burdens of childbearing. Within the family they become increasingly influential in childbearing decisions.
- Improvements in contraceptive technology help in the second half of the 20th.C. However, contraceptives were not widely available in the 19th.C. and likely contributed little to the decline. Fertility decline is caused by a change in values than by simply the availability of contraceptives and knowledge of how to use them. *Today in the world there exists a close correspondence between fertility and contraceptive use, but this likely means that those families that have chosen to limit family size find contraceptives the easiest and most effective way to do so*.

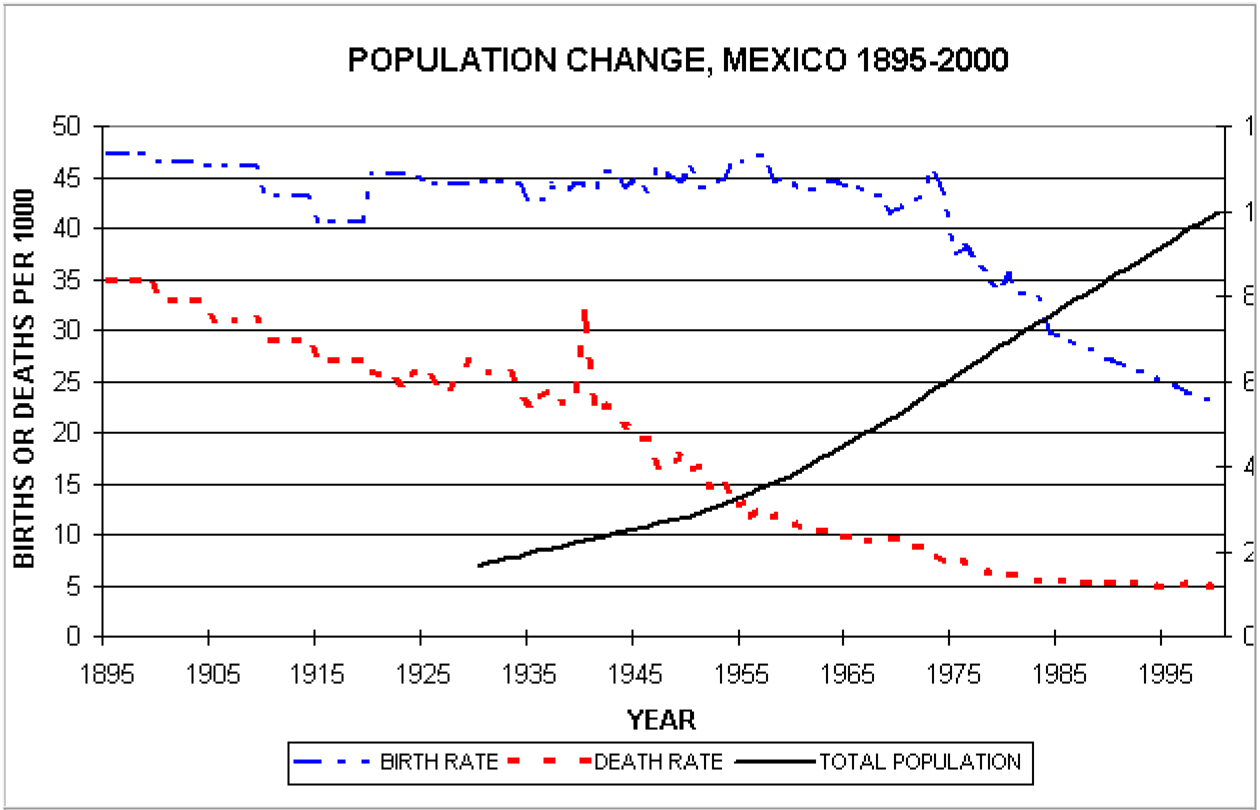
In the following figure, note that once infant mortality had fallen to around 70 (which occurred around 1910 in Sweden -- see figure above), then the fertility rate declines rapidly.

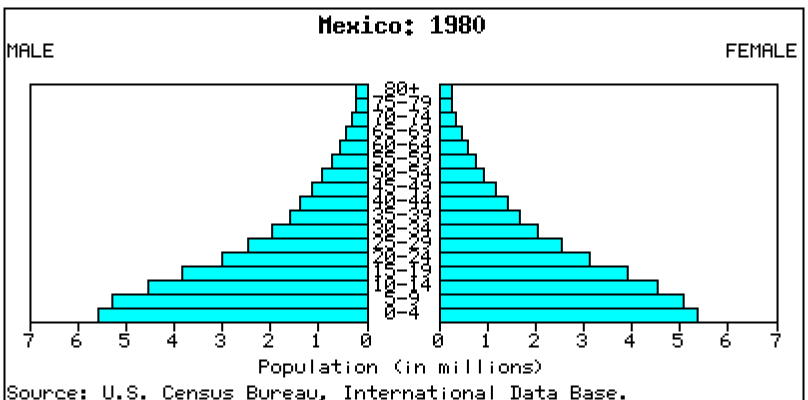


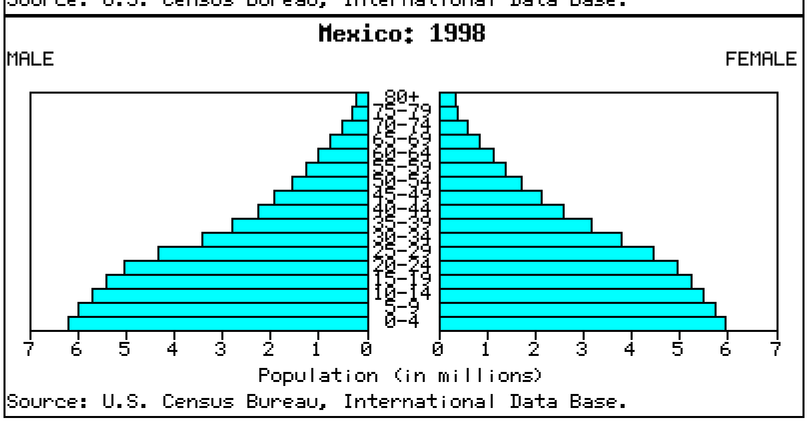
In a similar way, there is a close correspondence between fertility and infant mortality across the world today:



The age structure of a population entering Stage Three is illustrated below by using an example from the Third World today:

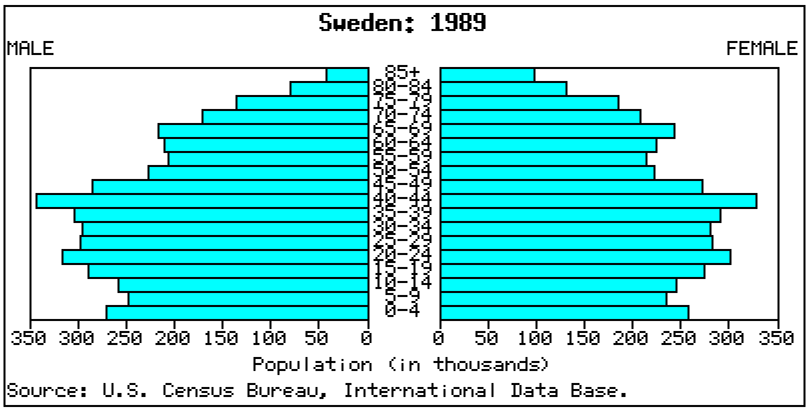

POPULATION CHANGE, MEXICO 1895-2000
BIRTHS OR DEATHS PER 1000
YEAR
BIRTH RATE
DEATH RATE
TOTAL POPULATION


Mexico: 1980
MALE
FEMALE
Population (in millions)
Source: U.S. Census Bureau, International Data Base.


Mexico: 1998
MALE
FEMALE
Population (in millions)
Source: U.S. Census Bureau, International Data Base.

In Mexico one can see the decline in growth by means of its increasing impact on the age structure. The youngest base of the population is no longer expanding.

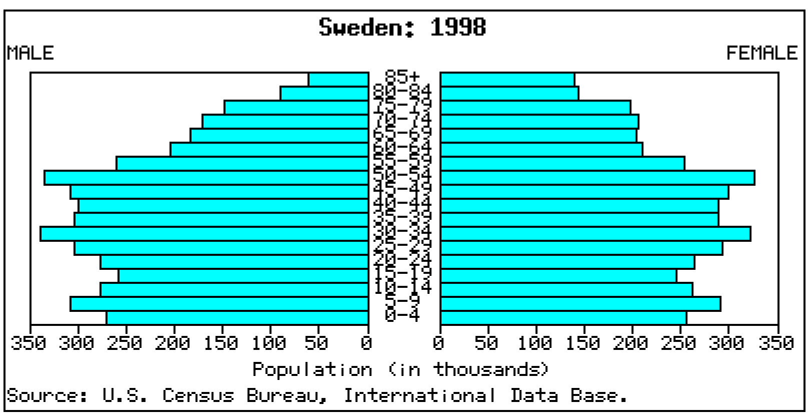
At some point towards the end of Stage Three the fertility rate falls to replacement levels. However population growth continues on account of population momentum. This can be seen in the Mexico example, and it is responsible for the continued growth in the population of Sweden in the 1980s. An animation of population momentum in Indonesia can be viewed HERE.



Demographic Indicators

Birth Rate: 13 per thousand
Total fertility rate: 1.9 births
Natural increase: 0.3% per year 1990-2000
Age structure: 19% under 15 yrs.age

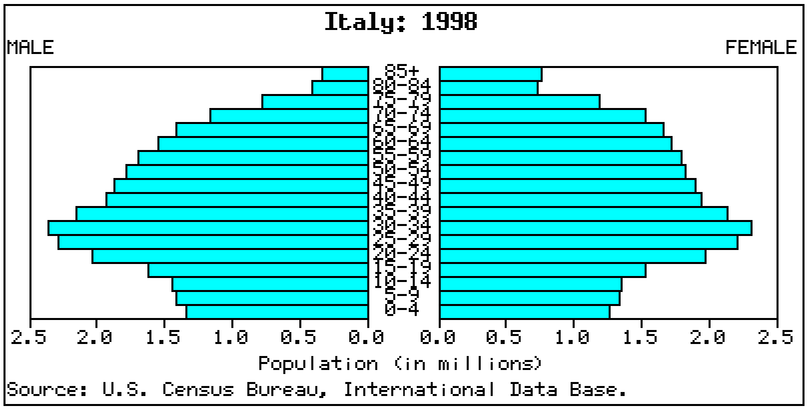
STAGE FOUR is characterized by stability. In this stage the population age structure has become older:



Demographic Indicators

Birth Rate: 12 per thousand
Total fertility rate: 1.8 births
Natural increase: 0.1% per year 1990-2000
Age structure: 18% under 15 yrs.age

In some cases the fertility rate falls well below replacement and population decline sets in rapidly:



Demographic Indicators

Birth Rate: 9 per thousand
Total fertility rate: 1.2 births
Natural increase: -0.1% per year 1990-2000
Age structure: 14% under 15 yrs.age

THE TRANSITION IN LESS WELL DEVELOPED COUNTRIES

Mexico and Sweden illustrate the salient differences and similarities between less and more developed countries.

These differences include:

1. A later (20th.C.) transition in LDCs.
2. A faster decline in death rates (50 yrs. vs. 150 yrs.). Death control has been imported from MDCs and applied rapidly. In most LDCs childhood mortality remains high, but 1/3 to 1/2 what it was 50 years ago. However the most rapid improvements have occurred in places in which female literacy has increased the most. Therefore, it is not simply the application of modern drugs that is responsible but, rather, behavioral changes that have improved survival (e.g. changes related to hygiene). These types of behavioral change are readily adopted because, in so far as they improve survival, they act to support traditional values that favor life over death in almost all societies.
3. A relatively longer lag between the decline in death rates and the decline in birth rates (death rates are lower before decline in birth rate starts). Fertility change requires a more conscious effort than mortality change and requires social and behavioral changes that conflict more with traditional values. This has been slower coming in LDCs because economic change has been delayed in many cases. The same economic pressures that existed in urban areas 100 years ago in MDCs have been slower to develop in LDCs because many, particularly in Africa, remain very rural. Hence, attitudes and values have been slower to change.
4. Higher maximum rates of growth in LDCs: over 3.5% growth per year at the height of Stage 2 in Mauritius and Mexico, compared to 1.3% in the same stage in Sweden. Also, therefore, age structures are far younger in LDCs. These data yield doubling times of 20 years versus 55 years.

But the greatest **similarity** concerns the fertility behavior of both populations (at different times) with respect to infant mortality. here shown for Brazil, Chile and Sweden:

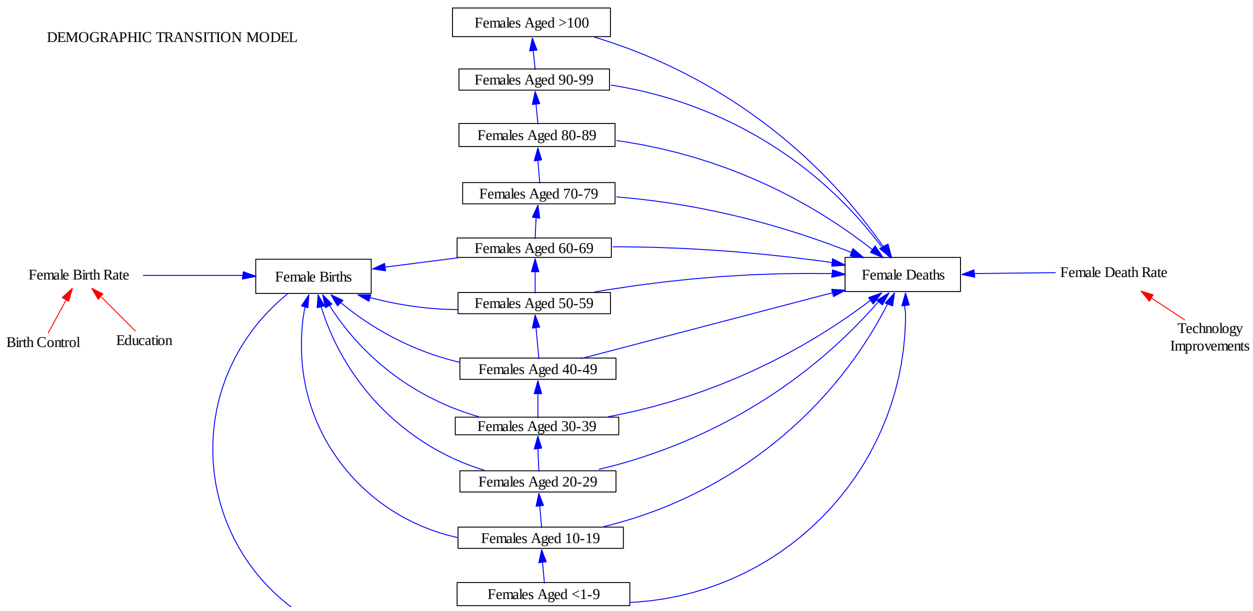
ANOTHER FORM OF THE TRANSITION

The demographic transition model summarizes change in population growth **over time**. Another form of transition exists in the world today and is associated with the differences in growth rates across countries of differing wealth. This is implied by the alternative labels on the traditional transition model (pre Modern, Urbanizing/Industrializing, etc.).

APPENDIX 3: EVOLUTION OF THIS MODEL

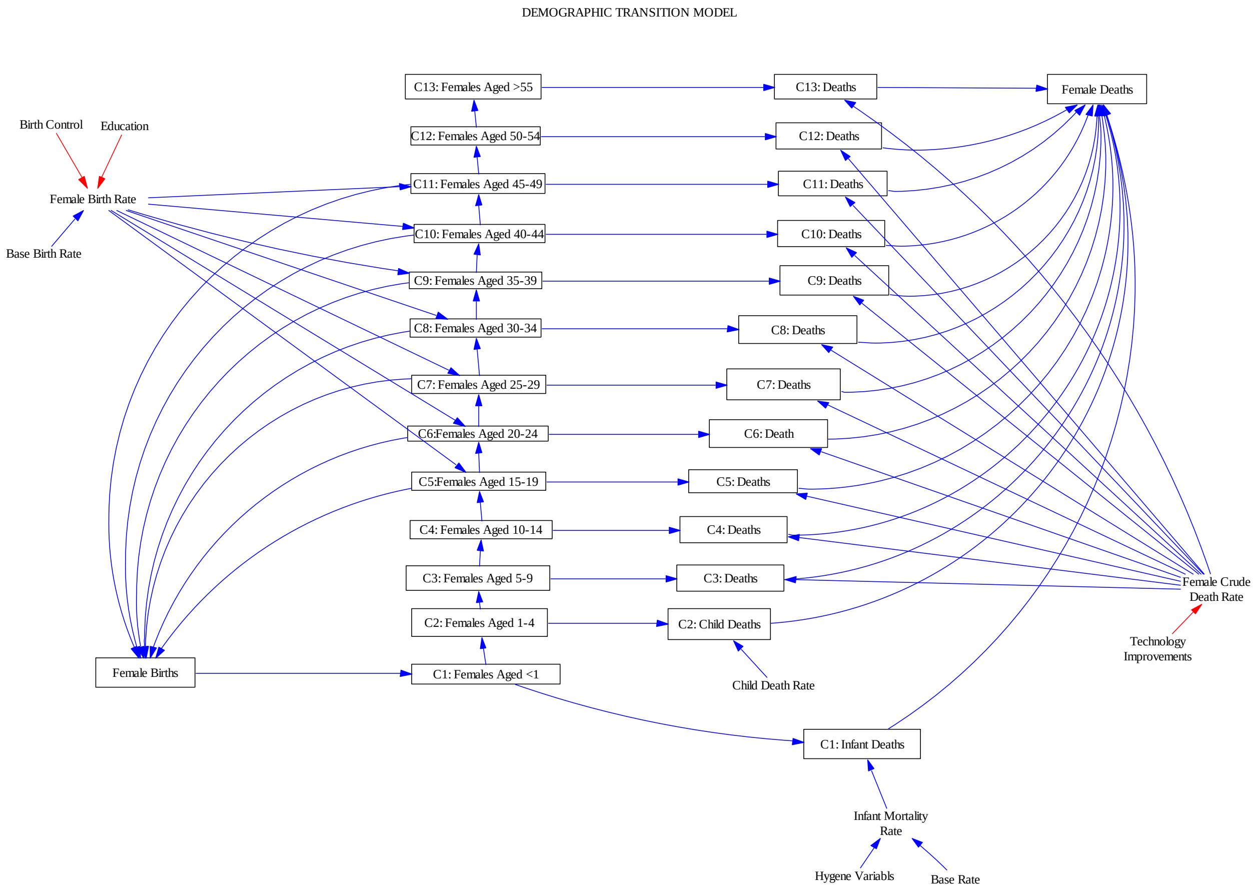
This model dramatically expanded from the original scope.

VERSION 1: THE INITIAL MODEL



VERSION 2: HEATHER SCHLEGEL

This model included equations

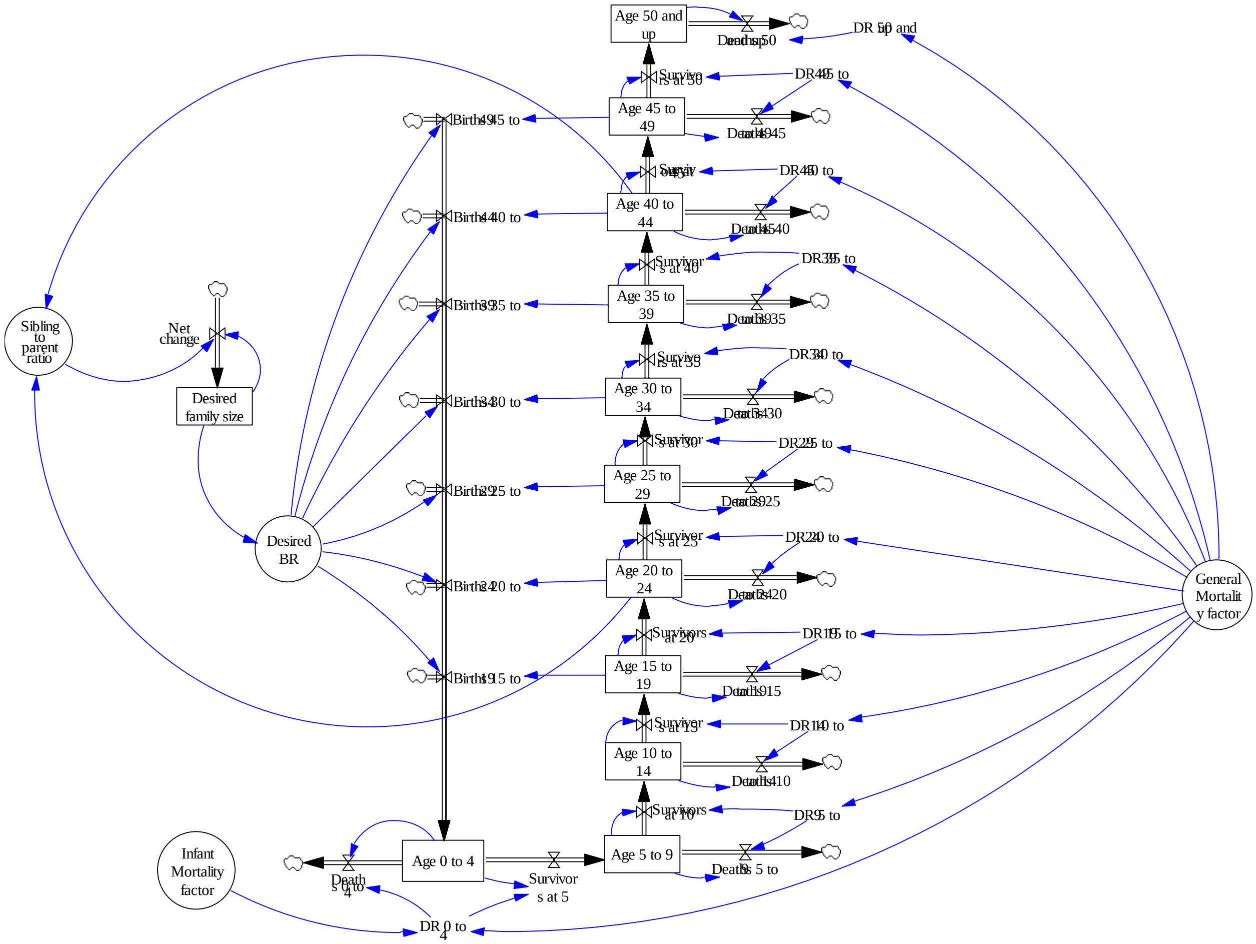


These were the initial equations:

Female Birth Rate = lookup table (?)
Female Births = C5+C6+C7+C8+C9+C10+C11= C1
C1: Female Births * infant mortality rate
C2: C1 (survivors) *under 5 mortality rate
C3: C2 (survivors) * crude death rate
C4: C3 (survivors) * crude death rate
C5: [C4 (survivors) * crude death rate] also [C4 (survivors) * birth rate] to female births
C6: [C5 (survivors) * crude death rate] also [C5 (survivors) * birth rate] to female births
C7: [C6 (survivors) * crude death rate] also [C6 (survivors) * birth rate] to female births
C8: [C7 (survivors) * crude death rate] also [C7 (survivors) * birth rate] to female births
C9: [C8 (survivors) * crude death rate] also [C8 (survivors) * birth rate] to female births
C10: [C9 (survivors) * crude death rate] also [C9 (survivors) * birth rate] to female births
C11: [C10 (survivors) * crude death rate] also [C10 (survivors) * birth rate] to female births
C12: C11 (survivors) * crude death rate
C13: C12 (survivors)* crude death rate
Female Deaths = C1+C2+C3+C4+C5+C6+C7+C8+C9+C10+C11+C12+C13
Female Death Rate =Look-up table(?)

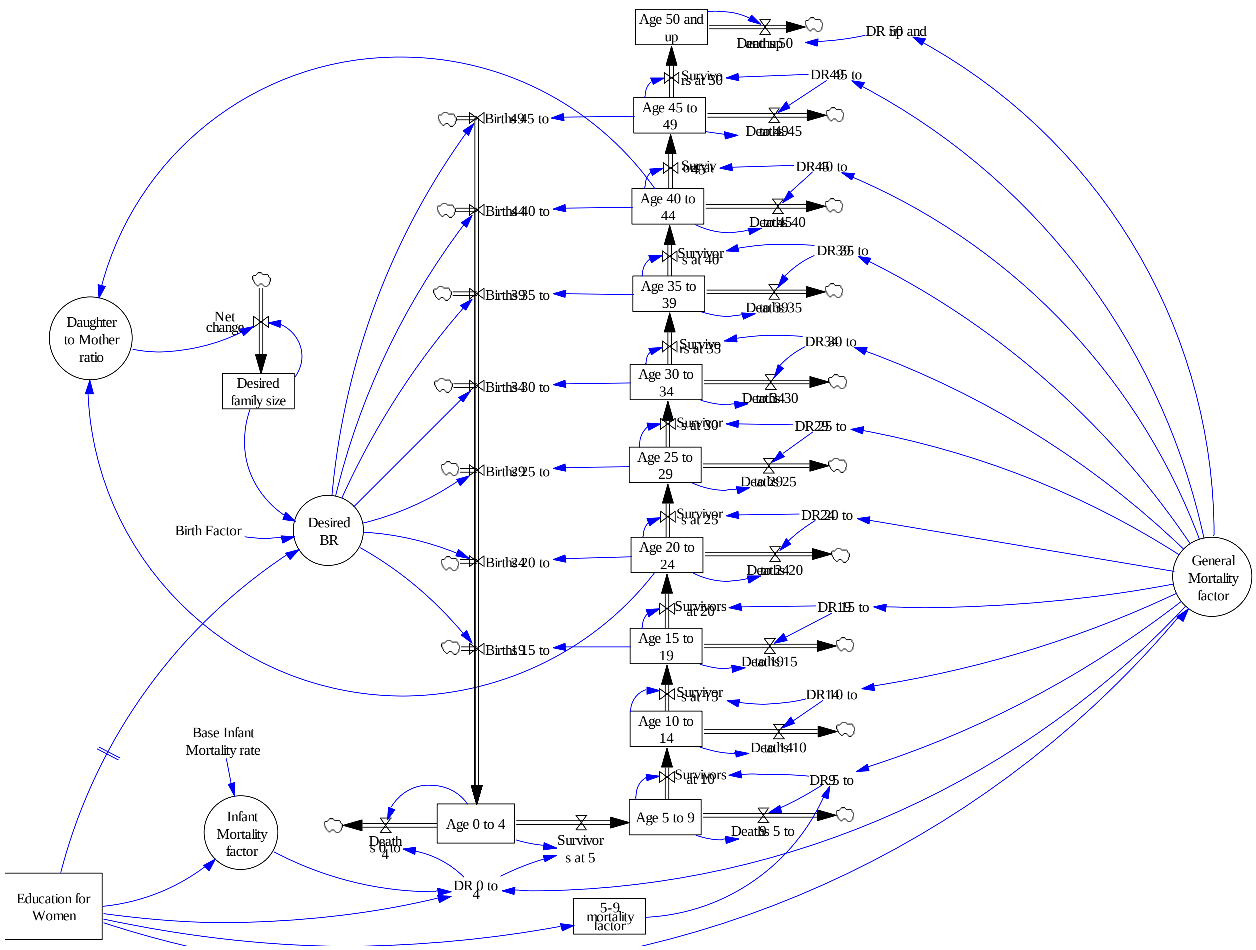
VERSION 3: DRAPER KAUFFMAN

D. Kauffman showed us how to change it into a stock and flow diagram.



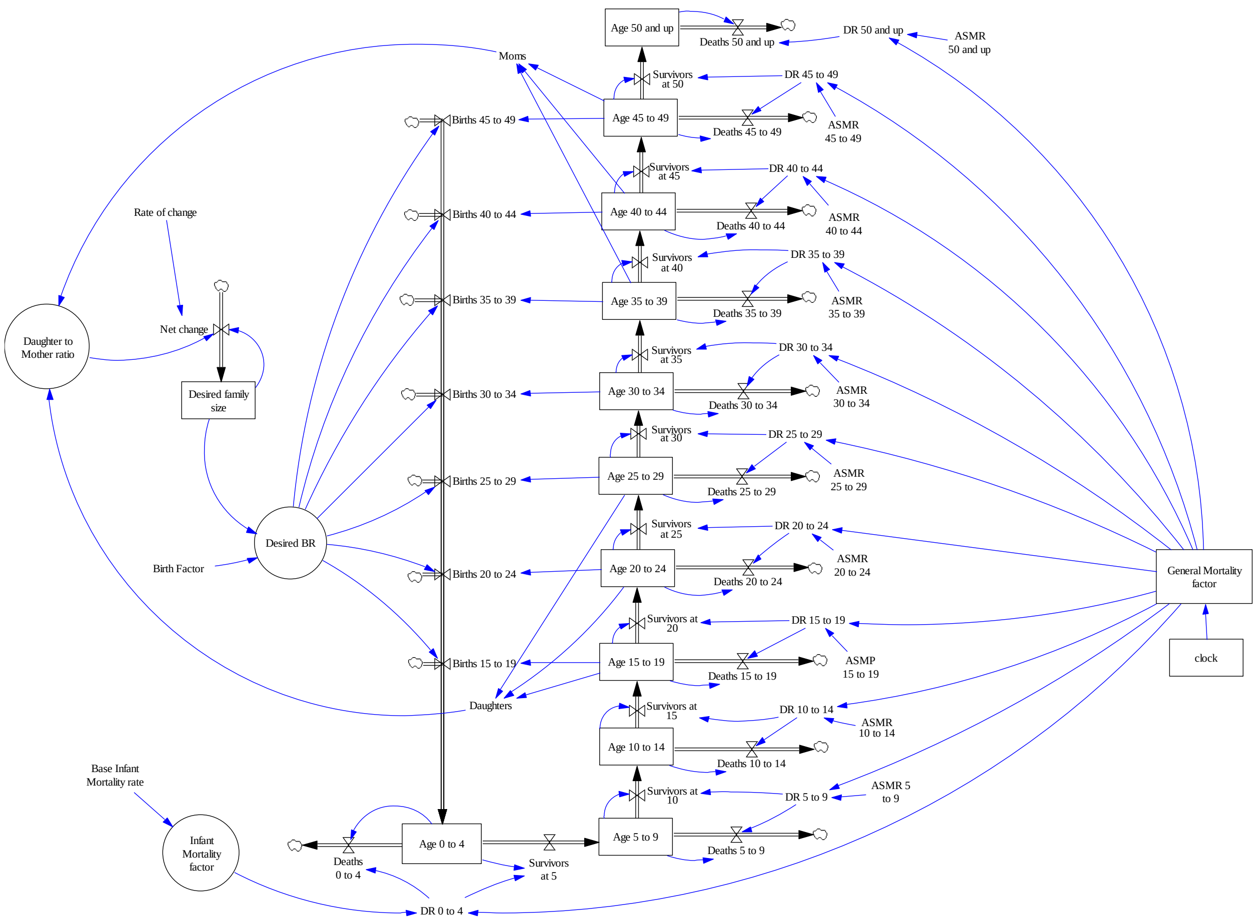
This model went through a few revisions with better data and modifications to the desired family size and sibling to parent ratio (daughter to mother ratio).

VERSION 5: EDUCATION STRUCTURAL CHANGE



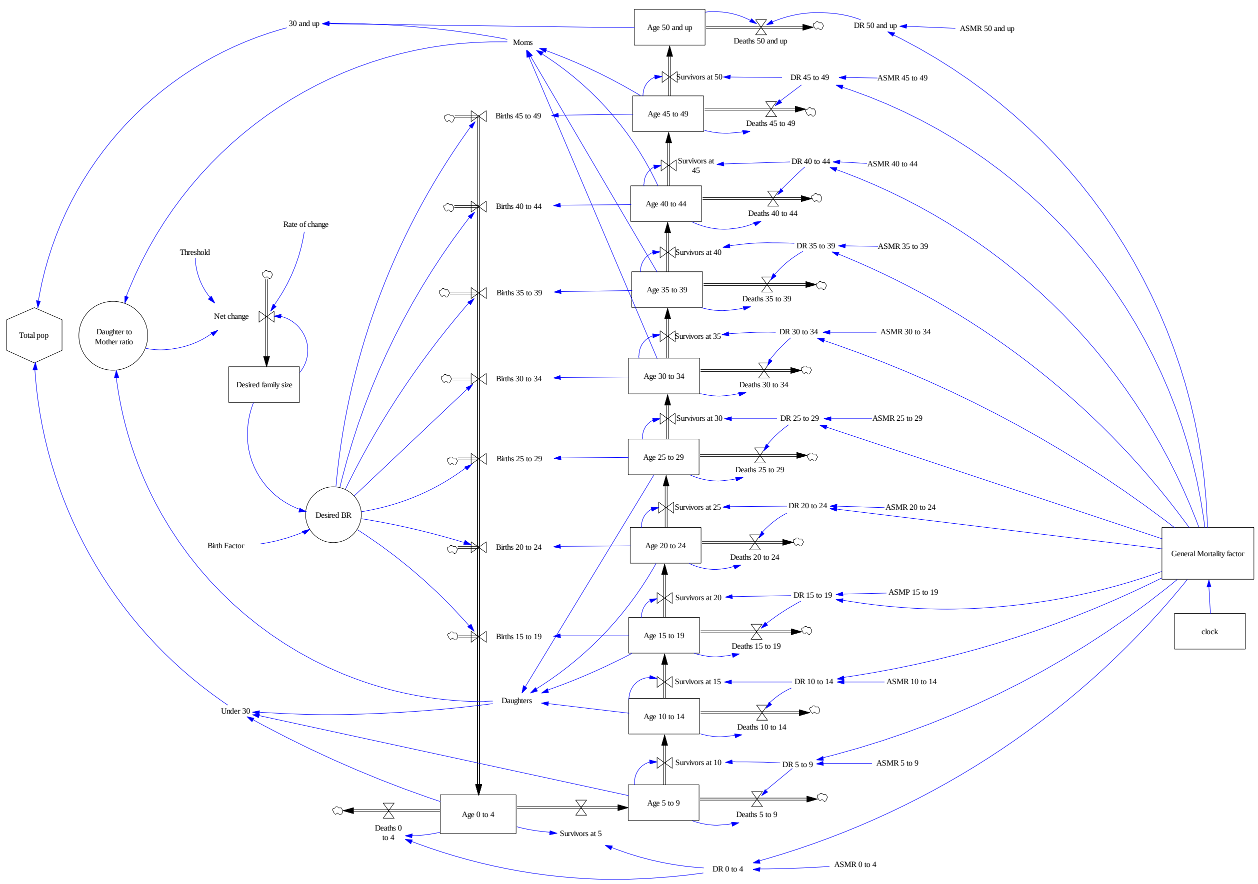
VERSION 9: ADDITION OF CLOCK AND ASMR

The ASMR were impossible to find, so we created the data values ourselves based on population pyramids of 2005 and 2010. We had to learn to create the ASMR. Previous versions shows using the crude death rate.



VERSION 11

Adds total population variable as well as the actual data from Nigeria (see Appendix: Data).



VERSION 12: FINAL (FOR NOW)

Final version of standard demographic transition. This model not including the literacy variable.