Guide to Formulas

Let

M(x,t) : *Population of male of age x at the year t*

F(x,t) : *Population of female of age x at the year t*

CF : *Child Policy/Fertility Rates*

C(x,t) : *Population of couple of age x at the year t*

CC(x,t,z) : *Number of couple of age x at the year t having z children*

NB(t) : *Number of new born babies at the year t*

NBM(t) : *Number of new born male babies at the year t*

NBF(t) : *Number of new born female babies at the year t*

NBC(x,t) : *Number of new born babies of couples of age x at the year t*

CPL(x,t) : *Child Policy Limit of the group of couple of age x at the year t*

dr(t) : *Forecasted death rate (probability that a person will die) at year t*

drc(t) : *Forecasted demise rate of a couple at year t*

br(x,t) : *Forecasted birth rate (number of birth per 1000 people) of age x at year t*

bprob(x,t) : *Probability that a couple of age x will give birth at year t*

TP(t) : *Total population at year t*

PM : *Proportion of new born babies that are male (in decimal or fraction form)*

PF : *Proportion of new born babies that are female (in decimal or fraction form)*

PSK(t) : *Number of persons per square kilometer at the year t*

LA : *Land area in square kilometer*

YP(t) : *Population of ages 0 to 17 at year t (Young Population)*

LP(t) : *Population of ages 17 to 59 at year t (Labor Population)*

SP(t) : *Population of ages 60 and above at year t (Senior Population)*

MN : *Net Migration*

MNc : *Net Migration of couple*

INPUT DATA

To compute the projection for year 1 to 100, the following data should be considered first:

- *M(x,0)* : *Initial population of male for age x; for x ϵ [0, 100]*
- *F(x,0)* : *Initial population of female for age x; for x ϵ [0, 100]*
- *CF* : *Child Policy or Fertility Rate (If child policy is not implemented)*
- *dr(t)* : *Forecasted death rate at year t*
- *br(x,t)* : *Birth rate (number of birth per 1000 persons) of age x at year t*
- *PM* : *Proportion of new born babies that are male (in decimal or fraction form)*
- *PF* : *Proportion of new born babies that are female (in decimal or fraction form)*
- *LA* : *Land area in square kilometer*
- *MN* : *Net Migration*

INITIAL COMPUTATION

$$TP(0) = \sum_{x=0}^{100} (M(x,0) + F(x,0))$$

$$bprob(x,t) = \frac{br(x,t)}{(1000)(0.5)\left(\sum_{x=18}^{45}\left(M(x,0) + F(x,0)\right)\right)}$$

COMPUTATION WITHIN A YEAR

$$TP(t) = \sum_{x=0}^{100} (M(x,t) + F(x,t))$$

$$drc(t) = 2dr(t) - dr(t)^2 \text{ (using principle of inclusion and exclusion)}$$

$$MNc = 2MN - MN^2 \text{ (using principle of inclusion and exclusion)}$$

$$\mathrm{C}(\mathrm{x},0) = \min\left(M(x,0), F(x,0)\right)$$

$$\mathrm{C}(0,\mathrm{t}) = \min\left(M(0,t), F(0,t)\right), 0 < t \leq 100$$

$$CPL(18,t) = \begin{cases} C(x,0) \times CF, if\ Child\ policy\ is\ implemented \\ 10000000000000000000, if\ Child\ policy\ is\ not\ implemented \end{cases}, 1 \leq t \leq 100$$

$$CPL(x,0) = \begin{cases} C(x,0) \times CF, if\ Child\ policy\ is\ implemented \\ 10000000000000000000, if\ Child\ policy\ is\ not\ implemented \end{cases}, 0 < x \leq 100$$

$$\mathrm{NBC}(\mathrm{x},\mathrm{t}) = \begin{cases} bprob(x,t)C(x,t), CPL(x,t) \geq bprob(x,t)C(x,t) \\ CPL(x,t), bprob(x,t)C(x,t) > CPL(x,t) \\ 0, CPL(x,t) \leq 0 \end{cases}$$

$$NB(t) = \sum_{x=18}^{45} NBC(x,t)$$

$$NBM(t) = NB(t)(PM)$$

$$NBF(t) = NB(t)(PF)$$

COMPARTMENT COMPUTATION**

(**MNc is negative, Net migration is negative)

If 0 child policy is implemented,

$$\mathrm{CC(x,t,0)} = \mathrm{CC(x-1,t-1,0)} - \big(\mathrm{CC(x-1,t-1,0)} * \mathrm{drc(t-1)}\big) + (\mathrm{CC(x,t-1,0)} * \mathrm{MNc}), 0 < t \leq 100 \; and \; 0 < x \leq 100$$

If 1 child policy is implemented,

$$\mathrm{CC(x,t,0)} = \mathrm{CC(x-1,t-1,0)} - \big(\mathrm{CC(x-1,t-1,0)} * \mathrm{drc(t-1)}\big) - (\mathrm{CC(x-1,t-1,0)} * \mathrm{bprob(x,t)}) + (\mathrm{CC(x,t-1,0)} * \mathrm{MNc}), 0 < t \leq 100 \; and \; 0 < x \leq 100$$

$$CC(x,0,1) = 0, \forall x$$

$$\mathrm{CC(x,t,1)} = \mathrm{CC(x-1,t-1,1)} - \big(\mathrm{CC(x-1,t-1,1)} * \mathrm{drc(t-1)}\big) + \big(\mathrm{CC(x-1,t-1,0)} * \mathrm{bprob(x,t)}\big) + (\mathrm{CC(x,t-1,1)} * \mathrm{MNc}), 0 < t \leq 100 \; and \; 0 < x \leq 100$$

If 2 child policy is implemented,

$$\mathrm{CC(x,t,0)} = \mathrm{CC(x-1,t-1,0)} - \big(\mathrm{CC(x-1,t-1,0)} * \mathrm{drc(t-1)}\big) - (\mathrm{CC(x-1,t-1,0)} * \mathrm{bprob(x,t)}) + (\mathrm{CC(x,t-1,0)} * \mathrm{MNc}), 0 < t \leq 100 \; and \; 0 < x \leq 100$$

$$CC(x,0,1) = 0, \forall x$$

$$CC(x,0,2) = 0, \forall x$$

$$\mathrm{CC(x,t,1)} = \mathrm{CC(x-1,t-1,1)} - \big(\mathrm{CC(x-1,t-1,1)} * \mathrm{drc(t-1)}\big) - \big(\mathrm{CC(x-1,t-1,1)} * \mathrm{bprob(x,t)}\big) + (\mathrm{CC(x-1,t-1,0)} * \mathrm{bprob(x,t)}) + (\mathrm{CC(x,t-1,1)} * \mathrm{MNc}), 0 < t \leq 100 \; and \; 0 < x \leq 100$$

$$\mathrm{CC(x,t,2)} = \mathrm{CC(x-1,t-1,2)} - \big(\mathrm{CC(x-1,t-1,2)} * \mathrm{drc(t-1)}\big) + (\mathrm{CC(x-1,t-1,1)} * \mathrm{bprob(x,t)}) + (\mathrm{CC(x,t-1,2)} * \mathrm{MNc}), 0 < t \leq 100 \; and \; 0 < x \leq 100$$

If 3 child policy is implemented,

$$\mathrm{CC(x,t,0)} = \mathrm{CC(x-1,t-1,0)} - \big(\mathrm{CC(x-1,t-1,0)} * \mathrm{drc(t-1)}\big) - (\mathrm{CC(x-1,t-1,0)} * \mathrm{bprob(x,t)}) + (\mathrm{CC(x,t-1,0)} * \mathrm{MNc}), 0 < t \leq 100 \; and \;\; 0 < x \leq 100$$

$$CC(x, 0,1) = 0, \forall x$$

$$CC(x, 0,2) = 0, \forall x$$

$$CC(x, 0,3) = 0, \forall x$$

$$\mathrm{CC(x,t,1)} = \mathrm{CC(x-1,t-1,1)} - \big(\mathrm{CC(x-1,t-1,1)} * \mathrm{drc(t-1)}\big) - \big(\mathrm{CC(x-1,t-1,1)} * \mathrm{bprob(x,t)}\big) + (\mathrm{CC(x-1,t-1,0)} * \mathrm{bprob(x,t)}) + (\mathrm{CC(x,t-1,1)} * \mathrm{MNc}), 0 < t \leq 100 \; and \;\; 0 < x \leq 100$$

$$\mathrm{CC(x,t,2)} = \mathrm{CC(x-1,t-1,2)} - \big(\mathrm{CC(x-1,t-1,2)} * \mathrm{drc(t-1)}\big) - \big(\mathrm{CC(x-1,t-1,2)} * \mathrm{bprob(x,t)}\big) + (\mathrm{CC(x-1,t-1,1)} * \mathrm{bprob(x,t)}) + (\mathrm{CC(x,t-1,2)} * \mathrm{MNc}), 10 < t \leq 100 \; and \;\; 0 < x \leq 100$$

$$\mathrm{CC(x,t,3)} = \mathrm{CC(x-1,t-1,3)} - \big(\mathrm{CC(x-1,t-1,3)} * \mathrm{drc(t-1)}\big) + (\mathrm{CC(x-1,t-1,3)} * \mathrm{bprob(x,t)}) + (\mathrm{CC(x,t-1,3)} * \mathrm{MNc}), 0 < t \leq 100 \; and \;\; 0 < x \leq 100$$

If 4 or more child policy is implemented,

$$\mathrm{CC(x,t,0)} = \mathrm{CC(x-1,t-1,0)} - \big(\mathrm{CC(x-1,t-1,0)} * \mathrm{drc(t-1)}\big) - (\mathrm{CC(x-1,t-1,0)} * \mathrm{bprob(x,t)}) + (\mathrm{CC(x,t-1,0)} * \mathrm{MNc}), 0 < t \leq 100 \; and \;\; 0 < x \leq 100$$

$$CC(x, 0,1) = 0, \forall x$$

$$CC(x, 0,2) = 0, \forall x$$

$$CC(x, 0,3) = 0, \forall x$$

$$CC(x, 0,4) = 0, \forall x$$

$$\mathrm{CC(x,t,1)} = \mathrm{CC(x-1,t-1,1)} - \big(\mathrm{CC(x-1,t-1,1)} * \mathrm{drc(t-1)}\big) - \big(\mathrm{CC(x-1,t-1,1)} * \mathrm{bprob(x,t)}\big) + (\mathrm{CC(x-1,t-1,0)} * \mathrm{bprob(x,t)}) + (\mathrm{CC(x,t-1,1)} * \mathrm{MNc}), 0 < t \leq 100 \; and \;\; 0 < x \leq 100$$

$$\mathrm{CC(x,t,2)} = \mathrm{CC(x-1,t-1,2)} - \big(\mathrm{CC(x-1,t-1,2)} * \mathrm{drc(t-1)}\big) - \big(\mathrm{CC(x-1,t-1,2)} * \mathrm{bprob(x,t)}\big) + (\mathrm{CC(x-1,t-1,1)} * \mathrm{bprob(x,t)}) + (\mathrm{CC(x,t-1,2)} * \mathrm{MNc}), 0 < t \leq 100 \;\; 0 < x \leq 100$$

$$\mathrm{CC(x,t,3)} = \mathrm{CC(x-1,t-1,3)} - \big(\mathrm{CC(x-1,t-1,3)} * \mathrm{drc(t-1)}\big) - \big(\mathrm{CC(x-1,t-1,3)} * \mathrm{bprob(x,t)}\big) + (\mathrm{CC(x-1,t-1,2)} * \mathrm{bprob(x,t)}) + (\mathrm{CC(x,t-1,3)} * \mathrm{MNc}), 0 < t \leq 100 \; and \;\; 0 < x \leq 100$$

$$\mathrm{CC(x,t,4)} = \mathrm{CC(x-1,t-1,4)} - \big(\mathrm{CC(x-1,t-1,4)} * \mathrm{drc(t-1)}\big) + (\mathrm{CC(x-1,t-1,3)} * \mathrm{bprob(x,t)}) + (\mathrm{CC(x,t-1,4)} * \mathrm{MNc}), 0 < t \leq 100 \; and \;\; 0 < x \leq 100$$

TRANSITION COMPUTATION PER EACH YEAR

$$M(0,t) = NBM(t-1)$$

$$F(0,t) = NBF(t-1) M(x,t) = M(x-1,t-1) - \big(M(x-1,t-1) * dr(t-1)\big) + (M(x,t-1) * MN), 1 \le x \le 100$$

$$F(x,t) = F(x-1,t-1) - \big(F(x-1,t-1) * dr(t-1)\big) + (F(x,t-1) * MN), 1 \le x \le 100$$

$$\mathrm{C(x,t)} = \mathrm{C(x,t)} - (\mathrm{C(x-1,t-1)} * \mathrm{drc(t-1)}) + (\mathrm{C(x,t-1)} * \mathrm{MNc}), 1 \le t \le 100 \; and \; 1 \le x \le 100$$

$$CPL(x,t) = \begin{cases} 0, if\ CP = 0 \\ CPL(x-1,t-1) - NBC(x-1,t-1) - drc(t-1) * CC(x-1,t-1,0) + MNc * CC(x,t-1,0), if\ CP = 1 \\ CPL(x-1,t-1) - NBC(x-1,t-1) - drc(t-1)[2 * CC(x-1,t-1,0) + CC(x-1,t-1,1)] + MNc * [2 * CC(x,t-1,0) + CC(x,t-1,1)], if\ CP = 2 \\ CPL(x-1,t-1) - NBC(x-1,t-1) - drc(t-1)[3 * CC(x-1,t-1,0) + 2 * CC(x-1,t-1,1) + CC(x-1,t-1,2)] + MNc * [3 * CC(x,t-1,0) + 2 * CC(x,t-1,1) + CC(x,t-1,2)], if\ CP = 3 \\ CPL(x-1,t-1) - NBC(x-1,t-1) - drc(t-1)[4 * CC(x-1,t-1,0) + 3 * CC(x-1,t-1,1) + 2 * CC(x-1,t-1,2) + CC(x-1,t-1,3)] + MNc * [4 * CC(x,t-1,0) + 3 * CC(x,t-1,1) + 2 * CC(x,t-1,2) + CC(x,t-1,3)], if\ CP = 4 \\ 10000000000000000000, if\ there\ is\ no\ Child\ Policy\ implemented \end{cases}$$

DENSITY COMPUTATION

$$PKS(t) = \frac{TP(t)}{LA}$$

YOUNG, LABOR & SENIOR POPULATION PERCENTAGE COMPUTATION

- Percentage of Young Population at year t $= \frac{YP(t)}{TP(t)}$
- Percentage of Labor Population at year t $= \frac{LP(t)}{TP(t)}$
- Percentage of Senior Population at year t $= \frac{SP(t)}{TP(t)}$