ECON 3710/4710 Demography of developing countries

Computer exercise 4: Spread of HIV infection in a population over time

Consider a sexually active population, which has 20 000 individuals at time $t = 0$. The population increases due to fertility and imigration, and it decreases as a result of mortality and outmigration. We shall ignore age.

The population at time 0 is split into 'high risk' and 'low risk' individuals, with 8 000 in the former group and 12 000 in the latter group. Individuals in the 'high risk' group have two new sexual partners per annum. Individuals in the low risk group have no contact with individuals in the high risk group.

At the end of every year, 1000 individuals enter the population (births, immigrants). Also, 2% of individuals leave the population for reasons other than AIDS mortality (emigration, non-AIDS mortality).

We make the following assumptions about the population and about HIV transmission dynamics:

- Initially (at time t = 0), there are 10 HIV-infected people in the high risk group.
- No infections occur in the low risk group.
- The probability of HIV transmission per partnership with an HIV-positive individual is 0.3.
- The annual probability of death due to AIDS (independent of non-AIDS mortality), in people infected with HIV, is 10%. In the calendar year in which they become infected, people are assumed not to experience any AIDS-related mortality.
- There is no provision of antiretroviral treatment in this population.
- New entrants to the sexually active population are all HIV-negative and 40% of new entrants are high risk (the remaining 60% are low risk).

We will model the spread of HIV infection in this population at annual intervals. To do this, we will use a table with the time since the start of the epidemic on the left hand side (101 rows, for t = 0, 1, 2, …, 100). It has the following column headings (see Excel spreadsheet):

- time
- # HIV-positive high risk at start of year
- # HIV-negative high risk at start of year
- # HIV-negative low risk at start of year
- Size of sexually active population at start of year
- HIV-prevalence at start of year
- Probability of HIV infection over the year, for an individual who is HIV-negative and high risk at the start of the year
- # new HIV infections
- # AIDS deaths

Starting populations in the high risk group and in the low risk group are given. An important variable is the prevalence of HIV+, i.e. the number of HIV+ individuals as a fraction of the population.

1. Compute the prevalence of HIV+ at time t=0. Store the result in column F, row 13 (t=0).

Column G has the probability to become infected during a year, for a person who was not infected at the beginning of the year, but who belongs to the high risk group. This probability is quite complicated. I specified it for the first year. The expression is

$$1-\left[1-\left(\frac{B13}{B13+C13}\right)G7\right]^{G6}$$

$\frac{B13}{B13+C13}$ is the share of infected individuals in the high risk group. It gives the chance that a person in the high risk group starts a partnership with someone who is infected.

$\frac{B13}{B13+C13}G7$ (with G7=0.3) is the annual probability of infection per new partner. One minus the latter experession is the corresponding chance NOT to become infected. It is raised to the power 2 (in cell G6) to find the probability of NOT becoming infected when there are two new partners during a year. Hence one minus the latter expression gives the chance of becoming infected.

2. Compute the number of new infections during year 0. Store the result in H13.

3. Compute the number of AIDS deaths. It is equal to the number of infected individuals times the death probability due to AIDS times the probability of NOT dying from other causes (one minus G5). Store the result in J13.

We are now done with the first year (t=0). To compute the second year (t=1) you do the following.

4. Update the # HIV+ in the high risk group (column B). That number equals the previous number (cell B13) multiplied by the AIDS survival probability (one minus G8). To this we add the number of new infections from H13. The sum has to be multiplied by the probability of NOT dying from other causes than AIDS (one minus G5). Store the result in cell B14.

5. Update the number of HIV- in the high risk group. It equals the previous number (in C13) minus those who became infected (H13). This number has to be multiplied by the probability of not dying of AIDS (one minus G5). To this we have to add the number of entrants (G3) times the share of high risk among new entrants (G2). Store the result in C14.

6. The final new calculation concerns an update of the number of HIV- in the low risk group. It equals the previous number (in D13) multiplied by the probability of not dying of AIDS

(one minus G5). To this we have to add the number of entrants (G3) times the share of low risk among new entrants (1-G2). Store the result in D14.

7. Copy the expressions for total population (E14), prevalence (F14), probability of infection (G14), number of new infections (H14) and AIDS deaths (J14) from row 13 over to row 14.

8. Complete the simulation for 100 years by copying row 14 over to rows 15-113.

Two graphs will appear: one for prevalence and probability to become infected, and one for absolute numbers of individuals in the three risk groups. Comment on these graphs – focus on the long term behaviour of this population.

We will experiment with the model by successively changing values of the following input parameters:

- initial numbers of infections (G4)

- number of partners in high-risk group (G6)

- probability of infection per partnership in high-risk group (G7)

- rate of AIDS mortality (G8)

We will increase and decrease these parameters by 50% and study the impact each change has on the long-run characteristics of the population. The variables of interest are the prevalence rate and total population size.

Questions:

- Is the initial number of infections important for long term prevalence, for long term population growth?

- Is the number of partners in the high risk group important for long term prevalence, for long term population growth?

- Is the probability of infection per partnership important for long term prevalence, for long term population growth?

- Why does long term prevalence increase when the rate of AIDS mortality is halved?