U.S.A. – Country Zero for the AIDS epidemic? (by James Thompson) [1]

Let country zero be one where a stand-alone AIDS epidemic exists. Let the number of infected individuals in country zero be z. If the fraction of infected individuals is very low in country j, then the susceptible pool in country j is approximately constant. Let the number of infected individuals in j be x_J. Let the case rate in country zero divided by that in country j be c_J. Suppose c_J is constant. Let the rate of growth of AIDS be β_t. Let the number of people in country j be N_J and that in country zero be N_z. Let $\alpha_{J,t}$ be the transmission rate into country j from the country itself and $\eta_{J,t}$ be the transmission rate into country j from country zero. Then,

$$\frac{dz}{dt} = \beta_t z, \quad \frac{dx_J}{dt} = \beta_t x_J.$$

Suppose that the transmission of the disease in a country is proportional to both the number infected in that country and the number infected in country zero. Then,

$$(z/N_z)/(x_J/N_J) = c_J,$$

$$\frac{dx_J}{dt} = \alpha_{J,t} x_J + \eta_{J,t} z = (\alpha_{J,t} + (N_z/N_J)\, c_J \eta_{J,t}) x_j = \beta_t x_J.$$

Assuming that infected individuals from various countries have relatively little effect on the number of infected individuals in country zero, then for a short time span,

$z(t) \approx z(0)\exp(\beta_t t)$. Then,

$$\frac{dx_J}{dt} = \alpha_{J,t} x_J + \eta_{J,t} z(0)\exp(\beta_t t).$$

Even if $\alpha_{J,t}$ is negative, the epidemic in country j can be sustained if the transmission from infected individuals in country zero is sufficiently high. Let country i also be contributing to country j. The comparative contribution of country zero with respect to country i is

$$\eta_{j,t} = [(c_i N_J)/(c_J N_i)]\eta_{i,t} + (\alpha_{i,t} - \alpha_{J,t})N_J/(c_j N_z).$$

Let us suppose $\alpha_{i,t} = \alpha_{J,t}$. Then $x_J/x_i = \eta_{J,t}/\eta_{i,t}$ and $\eta_{J,t} = [(c_i N_J)/(c_J N_i)]\eta_{i,t}$.

By mid-1997, the cumulative AIDS cases in the U.S. were 612,078 while that in Canada were 15,101. The U.S. population is 9.27 times that of Canada. 612078/15101 = 40.53. Per capita, the incidence of AIDS in the U.S.A. by mid-1997 was comparatively 40.53/9.27 = 4.37 times that in Canada.

In Canada, when the epidemic, as a stand-alone, is just at the edge of sustainability,

$\alpha_{Can} = 0$ and $\eta_{Can,\,t} = ((N_{Can}/N_{USA})\beta_t)/c_{Can} = \beta_t/(9.27*4.14) = 0.026\beta_t$.

Hence, activity rates from infected Americans roughly 2.6% that experienced in the U.S. could sustain a Canadian epidemic at a comparative ratio of approximately 4 U.S. cases per Canadian case. For infected Canadians to be causing an epidemic in the U.S., the activity rate of infected Canadians with American susceptibles must be 1/0.026 = 38.5 times that of infected Canadians with Canadian susceptibles.

Similarly, $\eta_{France,\,t} = 0.076\beta_t$, $\eta_{United\ Kingdom,\,t} = 0.024\beta_t$, $\eta_{Denmark,\,t} = 0.0034\beta_t$, and $\eta_{Netherlands,\,t} = 0.0075\beta_t$.

Given the same growth rate of AIDS in the First-World, in spite of the considerably larger number of cases in the U.S. compared to other countries, the U.S. is driving the epidemic in the other First-World countries.

References:

1. Thompson JR. Is the United States country zero for the First-World AIDS epidemic? *J Theor Biol.* Jun 21 2000;204(4):621-628.