Estimated population mixing by country and risk cohort for the HIV/AIDS epidemic in Western Europe

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Abstract. This paper applies a compartmental epidemic model to estimating the mixing relations that support the transfer of HIV infection between risk populations within the countries of Western Europe. To this end, a space-time epidemic model with compartments representing countries with populations specified to be at high (gay men and intravenous drug injectors ever with AIDS) and low (the remainder who are sexually active) risk is described. This model also allows for contacts between susceptible and infectious individuals by both local and international travel. This system is calibrated to recorded AIDS incidence and the best-fit solution provides estimates of variations in the rates of mixing between the compartments together with a reconstruction of the transmission pathway. This solution indicates that, for all the countries, AIDS incidence among those at low risk is expected to remain extremely small relative to their total number. A sensitivity analysis of the low risk partner acquisition rate, however, suggests this endemic state might be fragile within Europe during this century. The discussion examines the relevance of these mixing relationships for the maintenance of disease control.

Key words: HIV/AIDS, Western Europe, compartmental modelling, population mixing, sensitivity analysis

JEL classification: C61, C63, I1

1 Introduction

Recorded AIDS incidence by nation has been typified by distinctive variations in the predominant risk behaviour (Chin and Mann 1988). In Western Europe, for example, the incidence in the northern countries is mainly among gay men, while in the south HIV infection is most frequent among intravenous drug users (IVDUs). These variations, however, are only partially attributable to the relative frequencies of these

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behaviours among a particular national population. More crucial for understanding the origins of sustained transmission is the rate at which the relevant risk activity is undertaken. In this respect, the theory of sexually transmitted disease (STD) epidemics indicates any segment of the population may act as a core for the spread of such infections if their average rate of partner acquisition is in excess of a given critical starting threshold (Jacquez et al. 1995; Sattenspiel and Simon 1988; Simon and Jacquez 1992). More recently, these ideas have been extended to derive equivalent thresholds for populations distributed over a set of regions to permit analysis of the HIV/AIDS epidemic as a space-time system (Thomas 1999a, b; Thomas and Smith 2000).

Following these developments, this paper applies a compartmental epidemic model to estimating the mixing relations which support the transfer of HIV infection between risk populations within the countries of Western Europe. To this end, Sect. 2 describes a space-time epidemic model with compartments representing countries with populations specified to be at high (gay men and IDVs ever with AIDS) and low (the remainder of the population who are sexually active) risk. This model also allows for contacts between susceptible and infectious individuals by both local and international travel. In Sect. 3, this system is calibrated to recorded AIDS incidence and the best-fit solution provides estimates of variations in the rates of mixing between the compartments together with a reconstruction of the transmission pathway. This solution indicates that, for all countries, AIDS incidence among those at low risk is expected to remain extremely small relative to their total number. Section 4, however, undertakes a sensitivity analysis of the low risk partner acquisition rate which suggests this endemic state might be fragile within Europe during this century. The discussion examines the relevance of these mixing relationships for the maintenance of disease control.

2 A multiregion model with risk cohorts and variable travel opportunities

2.1 Contact formation and partner selection

Multiregion modelling systems have a long history of application to infectious disease diffusion (Baroyan and Rvachev 1967; Murray and Cliff 1977; Longini et al. 1986; Flahault and Valleron 1992; Williams and Rees 1994; Sattenspiel and Dietz 1995; Toubiana and Vibert 1998). The particular system applied here employs principles of spatial interaction theory to the formation of regional contacts and allows for differences in the response of local and international journeys to increasing travel distance (Thomas 1999b; Thomas and Smith 2000). Let identify each of the regions forming the area of interest and denote journey type such that \( f = 1 \) is international and \( f = 2 \) is local. Then, the likelihood of travel between regions is generated according to a negative exponential function of the form \( e^{-\lambda_f d_{ij}} \), where \( d_{ij} \) is the distance between the centres of regions \( i \) and \( j \). Here, \( \lambda_f, \forall f \), are decay parameters calibrated in the interval \([0, \infty]\) to represent the sensitivity of the two travel types to this spatial separation. The decay parameter for international journeys, \( \lambda_1 \), will be significantly less than that for local journeys, \( \lambda_2 \), to indicate the relatively low sensitivity of international travel to this effect. Accordingly,

\[
a_{ijf} = e^{-\lambda_f d_{ij}}, \quad \forall i,j,f,
\]

(1)

denotes the accessibility of region \( i \) to \( j \) for travel of type \( f \), where the condition

\[
a_{ijf} = 0, \quad \forall i = j, \quad f = 1,
\]

(2)