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A three-state dynamical model for religious affiliation

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HIGHLIGHTS

- Presents a generalised class of the 'three state' model of social groups.
- A range of these models are examined in relation to data for religious commitment in post WWII Northern Ireland.
- These models suggest that there have been negligible religious conversion/reconversion rates with in Northern Ireland over the last 70 years.

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ABSTRACT

In the last century the western world has seen a rapid increase in the number of people describing themselves as affiliated with no religious group. We construct a set of models using coupled differential equations in which members of a society can be in one of three groups; religiously committed, religiously affiliated or religiously not affiliated. These models are then used to analyse post World War II census data for Northern Ireland.

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1. Introduction

The decline in religious belief, and corresponding rise in religious non-affiliation, in the western world over the last century is well attested. However, even though in decline, religion has shown, as Chaves [1] puts it, a 'stubborn refusal to disappear'. This 'stubborn refusal' has encouraged studies over the last 20 years to investigate a number of aspects of religious belief, by a range of economists, sociologists, mathematicians and physicists. Iannacone [2] and Stark and Iannaccone [3] have modelled religious groups as a religious market analogous to an economic market and argued that this explains why nations with state established denominations which have a monopoly on religion exhibit much lower rates of church attendance than countries with a 'competitive religious market' of multiple denominations. Indeed, Iannaccone [2] suggests that this 'religious market' approach explains the high figures for religious belief in the United States 'where the first amendment's anti-establishment clause has left the religious market virtually unregulated for the past 2 centuries'. Uecker et al. [4] have analysed the decline of religious belief in American early adults. While decline in religious belief in this group has previously been linked with entry into higher education, with accompanying exposure to alternative worldviews and erosion of the plausibility of religious belief, their data from the National Longitudinal Study of Adolescent Health suggested that there is 'little support' for such an assumption. Rather they suggested that early adults adopting behaviours such as non-marital sexual activity, frequent alcohol consumption, or drug use, may lead to dissociation from religious groups which teach that such behaviour is wrong. McCleary and Barro [5] have sought to find statistical links between specific religious beliefs and the work-ethic of believers, and both Herteliu [6] and Herteliu and Isaic-Maniu [7] classify a broad range of indicators which

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are of potential relevance to the modelling of religion. Tilley [8], and Voas and Crockett [9] analyse longitudinal data from the British Household Panel Survey which they conclude shows a major factor in decline in religious belief is its failure to efficiently transfer between generations. Voas and Crockett's results suggest that in Britain institutional religion has 'a half-life of one generation' i.e. the children of the current generation are half as likely to attend church as their parents. Hayward [10,11] has developed a model of how Christian churches grow, particularly in the context of religious revival, which is inspired by the classic mathematical model of the spread of epidemics introduced by Kermack and McKendrick [12]. This more general applicability of epidemiological models is emphasised by the fact that Bettencourt et al. [13] also successfully used such models to study the spread of a scientific idea — namely Feynman diagrams — in USA, Japan and USSR in the late 1940s and 1950s. Ausloos and Petroni [14,15] have used the Johnson–Mehl–Avrami–Kolmogorov equation for crystal growth to model the change in size of a number of world religions. Instead of using the numbers of members of a group, Ausloos [16,17] has examined the dynamics of a small religious group, the Belgian Antionists, via data regarding their finances and number of temples. Further, Clippe and Ausloos [18] have applied Benford's law of leading digits to the finances of the Belgian Antionists, and Mir [19] has applied Benford's law to the size of seven religious faiths in countries across the world. Vitanov et al. [20] have used a Lotka–Volterra like model to consider competing ideologies, investigating cases of societies with up to three ideologies.

In contrast to these studies, many of which have investigated specific facets of the dynamics of religious belief, a recent paper by Abrams et al. [21] has extended earlier work by Abrams and Strogatz [22] on language death by using a simple two-state model for group dynamics to model conversion between those who declare themselves to be religious and those who do not. Labelling these groups X (religiously affiliated) and Y (not religiously affiliated), with the fraction of the total population in each group being x and y respectively they proposed a model of the form

$$\frac{\mathrm{d}x}{\mathrm{d}t} = yR_{yx}\left(x, u_x\right) - xR_{xy}\left(y, u_y\right) \tag{1}$$

where $R_{yx}\left(x, u_x\right)$ is the rate per unit time that an individual converts from group Y to group X, and $0 \leq u_x \leq 1$ is the perceived utility of group X. Abrams et al. proposed

$$R_{yx}\left(x, u_x\right) = cx^a u_x \tag{2}$$

and further noting that the entire population is divided into the complementary sets of religiously affiliated and not religiously affiliated,

$$x + y = 1 \tag{3}$$

and requiring that the utilities are of the form

$$u_x + u_y = 1 \tag{4}$$

the model was fitted to a range of data sets with the result that a best fit was found for $a = 1$. This has the important consequence that (1) reduces to

$$\frac{\mathrm{d}x}{\mathrm{d}t} = c\left(2u_x - 1\right)x\left(1 - x\right) \tag{5}$$

i.e. — the model becomes one of logistic growth. Although the Abrams et al. model unifies a significant number of data sets, a restriction of the model is that it divides the social group into only two sub-groups. While a two state system is economic in terms of modelling, it could be argued that a religious group can usefully be divided to distinguish between committed (or core) and non-committed (or peripheral) members. Thus, in this paper we investigate a class of three state models which allow for a greater range of behaviours within a society.

2. A three state model

We consider a society divided into three groups with regard to religious affiliation — the religiously committed, X, the religiously affiliated, or non-committed, Z and the religiously not affiliated, Y.

The division of the religious group into the committed and non-committed corresponds to the observation that although individuals may declare themselves as belonging to a particular religious group, this may not be reflected in active involvement — such as regular attendance at the group's acts of worship.

A general form of this three state model can be given as

$$\begin{aligned}
\frac{\mathrm{d}x}{\mathrm{d}t} &= -x\left(R_{XY}\left(y, \alpha_{XY}\right) + R_{XZ}\left(z, \alpha_{XZ}\right)\right) + yR_{YX}\left(x, \alpha_{YX}\right) + zR_{ZX}\left(x, \alpha_{ZX}\right) \\
\frac{\mathrm{d}y}{\mathrm{d}t} &= xR_{XY}\left(y, \alpha_{XY}\right) - y\left(R_{YX}\left(x, \alpha_{YX}\right) + R_{YZ}\left(z, \alpha_{YZ}\right)\right) + zR_{ZY}\left(y, \alpha_{ZY}\right) \\
\frac{dz}{\mathrm{d}t} &= xR_{XZ}\left(z, \alpha_{XZ}\right) + yR_{YZ}\left(z, \alpha_{YZ}\right) - z\left(R_{ZX}\left(x, \alpha_{ZX}\right) + R_{ZY}\left(y, \alpha_{ZY}\right)\right)
\end{aligned} \tag{6}$$

where, as before, $R_{IJ}\left(x, \alpha_{IJ}\right)$ is the rate per unit time that members convert from group I to group J, and α_{IJ} is a constant.

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