How Fundamentalism Takes Root: A Simulation Study *

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Abstract

We report agent-based simulations of religiosity dynamics in a spatially dispersed population. Agents' religiosity responds to neighbors via pairwise interactions as well as via club goods effects. A simulation run is deemed fundamentalist if the final distribution contains a sizable minority of very high religiosity together with a majority of lesser religiosity. Such simulations are more prevalent when parameter values shift from values reflecting traditional societies towards values reflecting the modern world. The simulations suggest that the rise of fundamentalism in the modern world is boosted by greater real income, lower relative prices for secular goods, less substitutability between religious and secular goods, and less time spent with neighbors. Surprisingly, the simulations suggest little role for the rise of long distance communication and transportation.

JEL-Classification: Z12, D79, D85, H49
Keywords: fundamentalism, club goods, agent-based models

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1 Introduction

In 1920, Curtis Lee Laws, an editor of the American Baptist publication *Watchman-Examiner* first coined the word "fundamentalism" to describe groups eager to defend what they saw as the fundamentals of the Christian Protestant faith (Hood et al., 2005). Since then, the word has been applied more broadly to include a Shia branch of Islam in Iran after the 1979 revolution, Hindutva adherents in India in the 1990s, and many other groups. Indeed, all major religions now have a vocal (and in some cases, violent) strand of adherents who reject much of modern world culture and urge a return to the pure fundamentals of their faith. Although the groups — which include Catholic traditionalists, Jewish haredim, Sunni salafi, and even groups of Bhuddists in Burma and Japan — seem likely to remain minorities within their religions, they demand our attention. Some of these groups have an outsized influence in national politics, and several are pivotal in some of the world's most intractable international conflicts.

Why did fundamentalism take root in so many parts of the world during the late 20th century? What underlying forces determine the size and influence of fundamentalist groups? These are deep questions unlikely to be answered fully in any single investigation. In the present paper, we seek some insights by means of a simulation model.

Simulation models seem especially appropriate for assessing a wide range of possible answers to our questions. One builds known features into the simulation and looks for emergent behavior that, although sometimes surprising at first glance, can on reflection build intuition and insight. Simulations complement but do not substitute for other approaches including case studies, econometric analysis of historical data and analytical models.

Our simulation model traces the "religiosity" of individual agents over time, as they interact directly with other individuals and also within peer groups. The idea is see how shifts in underlying parameter values that capture some aspects of modernity can affect the long-run distribution of religiosity.

Section 2 sets the stage by offering conceptual and historical perspectives on fundamentalism. Section 3 introduces the simulation model. It features peer group effects, which have their roots in the club goods approach of Iannacone (1992), as well as direct pairwise interactions among agents. Section 4 presents simulation results showing the comparative static

impact of key parameters, and connects those parameters to contrasts between traditional societies and the modern world. Section 5 summarizes the insights gleaned from the exercise, and suggests future research directions.

Appendices A and B contain supplementary material. Section A.1 briefly outlines the emergence of four major movements: Protestant fundamentalism in the United States in the 19th and 20th centuries, Hindu fundamentalism in India, Islamic fundamentalism (with a focus on Iran and Egypt), and Pentecostalism in Latin America. Section A.2 identifies ten main characteristics of fundamentalist movements, and Section A.3 discusses the extent to which our parameters capture aspects of the transition to modernity. Appendix B describes the simulation code in greater detail, and includes additional comparative static results.

2 Background and Related Literature

It would be desirable to begin with a generally accepted operational definition fundamentalism, but unfortunately none seems to exist. Iannaccone (1997) notes that even the multivolume *Fundamentalism Project* by M.E. Marty and R.S. Appleby (1991) was criticized for failing to provide a clear definition of fundamentalism and objective criteria for categorizing religious movements as fundamentalist and non-fundamentalist. However, in our reading, the key characteristics shared by most fundamentalist movements include a belief in the inerrancy of scripture, an unwillingness to compromise, setting sharp boundaries between members and non-members, behavioural requirements, militancy, charismatic leadership, and other factors (see, e.g., Emerson and Hartman 2006). Appendix A.2 presents a longer and more detailed list.

For present purposes, we distill fundamentalism down to two key characteristics. First, fundamentalists are characterized by an extremely high level of religiosity in comparison to the rest of the society. That religiosity is usually expressed by an unwavering attachment to a set of core beliefs, e.g., in the inerrancy of scripture. Second, fundamentalists form a relatively cohesive group in terms of the level of religiosity. This cohesion is typically achieved by introducing a set of behavioural requirements — e.g., for worship, dressing, and eating — for the members and by setting sharp boundaries between members and non-members.

Modernity refers to a large interconnected collection of modifications to traditional societies, as discussed further in Appendix A.3. Our simulation study focuses on the following modifications.

(1) Decline of social capital. This process was famously studied by Putnam (1995, 2000), who found that at the end of 20th century people belonged to fewer civic organiztions and met with family and friends less often than they used to a few decades earlier.

(2) Progress in communication and transport technology. Over the last 200 years, the world has witnessed an unprecedented progress in these two domains, with developments of the telephone, radio, television, the Internet, trains, automobiles, planes, etc.

(3) Increase of wealth and improvement of living standards. The 20th century has seen unprecedented growth in wealth and living standards around the world.

(4) Growth of secular opportunities. Modernity has brought many new secular opportunities for people such as new professions and new kinds of entertainment, mostly thanks to the progress in communication and in transport. In some countries (notably Turkey, Egypt and Iran) authorities in the early to mid-twentieth century imposed secularization.

(5) Religious activities becoming less compatible with the demands of secular activities. Educating children, observing holidays, and assisting those in need are examples of activities that traditionally combine religious and secular motives, but in the modern world these activities tend to occur in separate spheres. Also, the pace of modern life increases the opportunity cost of religious behavioral requirements.

Our simulations try to capture these modifications via shifts in parameters, and then show the impact on the long-run distribution of religiosity.

Our paper adds to a rapidly maturing literature on the economics of religion (Iyer, 2016). We draw on club goods models of religion, following the seminal paper by Iannaccone (1992). In Iannaccone's model, individuals choose how much effort and money to allocate to secular activity and how much to the participation in the religious club. Each individual benefits from the quality of the religious club, which is determined by the level of participation

of other individuals in it. By imposing behavioural requirements, religious clubs increase the cost of secular activity, which can be thought of as a tax on such activity. The paper shows that these unproductive costs of behavioural requirements can in fact increase the club members' welfare. More recent club models of religion include Berman (2000), Chen (2010), among others. Iannaccone (1997) discusses his club model of religion in the context of religious fundamentalism.

We extend Iannaccone's (1992) model in three important ways. First, our agents interact via a spatial network, in which each individual agent is affected most by nearest neighbors. Second, besides club interactions, our agents interact pairwise with their neighbors. Finally, our simulation is dynamic, and we trace how the religious participation of individuals evolves over time as they interact with each other in the network.

Our paper also adds to the literature on religious extremism and fundamentalism. This rich literature includes club models of religious fundamentalism (Iannaccone 1997, Berman 2000), and models of religious strictness (McBride 2015, Levy and Razin 2012). Our paper is also related to the literature on secularization and on simulation models of religion (Shy 2007). Within these strands of literature, our paper is most closely related to those that model the emergence and spread of religious extremism or fundamentalism. We are aware of only five such papers, as follows.

Arce and Sandler (2003) study the evolutionary stable equilibria of a game in which members of a general subpopulation are matched with members of a fundamentalist subpopulation and the matched pair then plays a Nash demand game. The Nash demand game could be interpreted as a game in which players decide on their shares of social control (over norms, religion, etc.). Arce and Sandler (2009) consider a similar model and introduce assortativity of pairwise matching, which allows them to study the role of isolation of fundamentalist groups.

Epstein and Gang (2007), like us, model religiosity as a single continuous variable that reflects the level of observance. They consider a population which consists of a leader of a sect and his followers. The leader faces a trade-off when choosing the optimal required level of observance: increasing the level of observance increases the followers' dependence on him, but as the level becomes higher and higher, some people may choose to leave because the costs are too high.

Makowsky (2012) is the paper most closely related to ours, because he also spatially embeds a club model of religion. Unlike us, he uses a cellular automaton, with agents are located on a fixed, regular two-dimensional lattice. Rather than a continuous variable for religiosity, he assumes a fixed set of religious groups, each of which requires a a particular level of sacrifice from its members, and labels as "extremist" the groups with the highest levels of required sacrifice. Initially, agents are randomly assigned to groups, but in each later round, an agent evaluates all groups in her neighborhood in the lattice and joins the utility-maximizing one. The model suggests that extremist groups are most successful when religious groups can produce goods that are close substitutes to secular goods. Makowsky (2011) omits the spatial aspects but otherwise has a setup similar to Makowsky (2012). The analysis here focuses on how a bimodal distribution of agents' commitment to their religious clubs can emerge in the population.

3 Simulation model

Our model traces the behavior over time of a fixed number of *agents*, stylized representations of individuals or families. Each agent $i = 1, ..., N$ is described at any time t by her physical location L_i and her degree of religiosity $r_i \in [0, 1]$. In this paper we hold L_i constant over time but simulate adjustments in religiosity r_i due to interactions with other agents. The analysis focuses on the distribution of religiosity in the long run, after the distribution seems to have settled down.

Our verbal definition of fundamentalism combined the group trait "extremely high level of religiosity in comparison to the rest of the society" with "cohesive ... in terms of the level of religiosity." We operationalize that definition as follows. First, sort the agents by religiosity in the final period so that $0 \leq r_1 \leq ... \leq r_i \leq r_{i+1} \leq ... \leq r_N$. Then, as illustrated in Figure 1, find the upper decile point $r_{[.90]}$ (for which 90% of the population has lower religiosity and 10% has higher), the median $r_{[.50]}$, and their midpoint (or cutoff value) $r^C = \frac{1}{2}(r_{[.50]} + r_{[.90]})$. Group 1 (the potential fundamentalists) consists of all i such that $r_i > r^C$, i.e., all agents whose religiosity is closer to the 90th percentile than to the median, and group 2 is everyone else.[1] Let μ_1 (or μ_2) denote the mean religiosity within group 1 (or group 2), and σ_1 (or σ_2)

[1] By construction, the potential fundamentalist group must constitute somewhere between .10 and .50 of

be the corresponding within-group standard deviation.

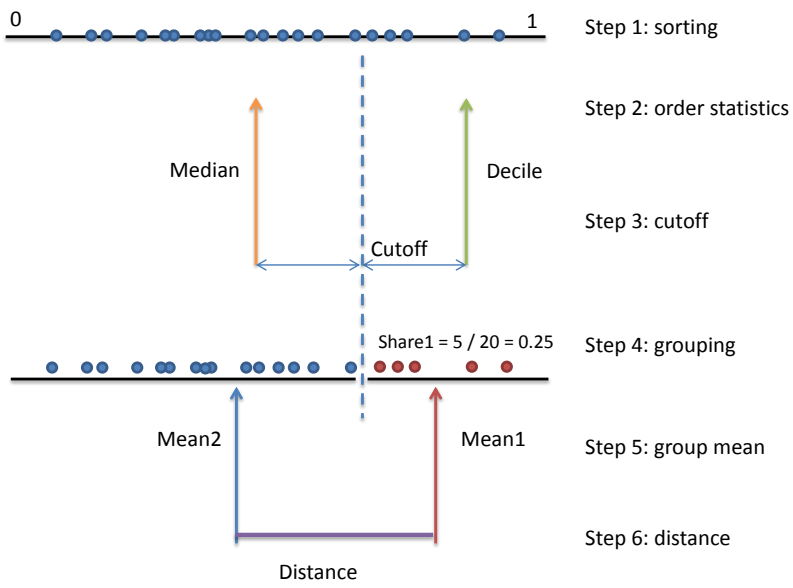

Figure 1: Operational Definition of Fundamentalism. A religiosity distribution exhibits fundamentalism ($F = 1$) if Mean1 and Distance are each sufficiently large.

We say that the distribution *exhibits fundamentalism* ($F = 1$) if

i. The group 1 mean $\mu_1 > 0.8$, i.e., group 1 has a high average degree of religiosity, and

ii. The distance $\mu_1 - \mu_2 > 0.2$, i.e., religiosity is, on average, noticeably higher in group 1 than in the rest of the population.

If either condition fails, we will say that the distribution fails to exhibit fundamentalism ($F = 0$). It will sometimes be helpful to say that a distribution *exhibits strict fundamentalism* ($\hat{F} = 1$) if, in addition to conditions i and ii above, we also have

iii. $X \equiv \max\left\{\frac{\mu_1 - r^C}{\sigma_1}, \frac{r^C - \mu_2}{\sigma_2}\right\} > X_{critical} = 2.23.$

Condition iii guarantees that at least one of the groups is not very dispersed. The critical value of 2.23 was chosen to ensure that there is less than a 5% chance that the condition

the population. Readers who believe that smaller or larger groups should qualify would have to tweak the percentiles defining the cutoff.

will be satisfied by an initial distribution with $N = 100$ drawn a uniform distribution on the unit interval.

3.1 Simulation procedure

The model begins by assigning initial locations and religiosities. The initial locations are assigned randomly and uniformly on the unit sphere, and directed links are created according to geodesic distance, using parameters described below. Locations and link strengths are permanent. Initial religiosities are independently uniformly distributed over the range $[0, 1]$. Figure 2 shows a typical example with $N = 20$ agents.

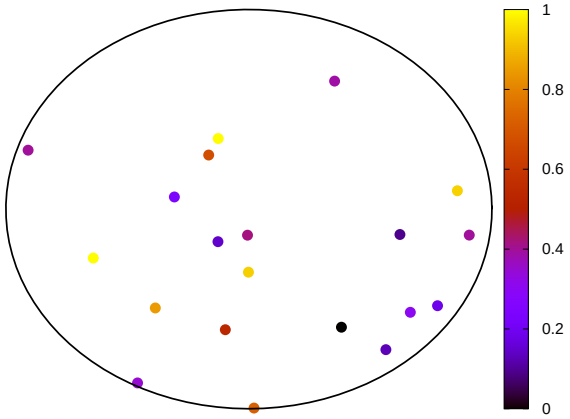

Figure 2: An Example of Simulation Initialization. The surface of the sphere is shown in Mollweide projection, a pseudo-cylindrical view that preserves areas but (especially towards the poles) distorts angles. Religiosities are color-coded from yellow (near 1.0) to dark violet (near 0.0).

Once initialized, the simulation updates agents' religiosities as follows. In each iteration, a directed link (from agent A, say, to agent B) is selected at random, with probability proportional to the link strength. The religiosity of agent A then is updated via an independent normally distributed random "noise" term n; a direct interaction term D that involves the religiosity of agent B; and peer group or "club goods" term C that involves the religiosity of all A's neighbors. Then another iteration is performed by selecting another link at random.

Each iteration transforms the chosen agent A's religiosity $r \in [0, 1]$ to a value $R \in$

$[-\infty, \infty]$ via the log odds function $R = \ln \frac{r}{1-r}$, then updates to $R' = R + C + D + n$, and finally transforms back to obtain agent A's new religiosity $r' = \mathcal{L}(R') \in [0, 1]$ via the inverse (or logit) transformation $\mathcal{L}(x) = \frac{\exp(x)}{1+\exp(x)} = (1 + \exp(-x))^{-1}$. The transformations make the updates essentially multiplicative and keep religiosity within the interval [0,1]. The next two subsections explain the update terms C and D in more detail.

Figure 3 tracks religiosities in a simulation of $N = 20$ agents for $T = 1$ million iterations. Note that two distinct groups emerge in the first quarter of the simulation, but they never become widely separated and the top group always has mean religiosity less than 0.8. Hence, according to our definition, fundamentalism did not emerge in this simulation ($F = 0$).

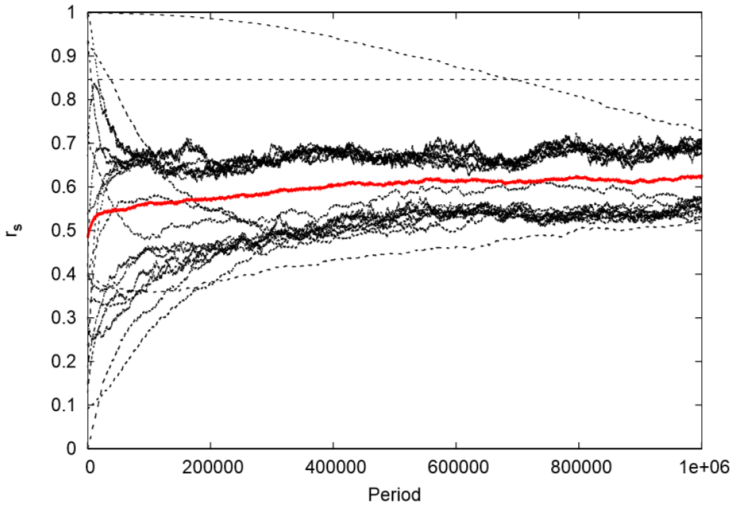

Figure 3: Simulation Example, with $N = 20$ and $T = 1,000,000$. Black dotted lines trace religiosities for each agent, and the red solid line is their overall mean.

3.2 Direct Interaction Parameters

The direct interaction term D arises from an agent's links to neighboring agents, and the size of the neighborhood is governed by parameter $K \in [0, 1]$. An agent has a link to every other agent located within geodesic distance $d \leq K$ so, for example, everyone in the same hemisphere is a neighbor when $K = 0.5$. The default value when $N = 100$ is $K = 0.16$, implying that a typical agent has about three neighbors.[2]

[2] As explained in Appendix B, we adjust K to keep the mean number of neighbors constant when varying N, and also adjust distant link strengths to keep them comparable to local link strengths.

Link strengths decrease in the distance between agents in the neighborhood; the strength is proportional to d^{b_d}, where the distance sensitivity parameter $b_d \in [-3, 0]$ has default value -1.0. In some simulations, we use the "small world" technique (Watts and Strogatz 1998) of breaking each link with probability $\beta \in [0, 0.5]$ and linking instead an agent selected at random irrespective of distance. The idea is that a few long distance links can greatly shorten the maximum path length, i.e., put agents on opposite sides of the world into much closer indirect contact. To avoid automatic attenuation of that effect, we introduce a new distance sensitivity parameter $b_{sm} \in [-3, 0]$ that applies to such links; the default is $b_{sm} = 0$. Thus link strength is governed by parameters K, β, b_d and b_{sm}.

The tolerance parameter $\lambda \in [0, 1]$ plays an important role. Once the link ij is chosen for updating (with probability proportional to its strength), the direct interaction effect is given by the equation

$$D = q(r_i - r_j)[(r_i - r_j)^2 - \lambda^2]. \tag{1}$$

If the religiosities of the two agents differ by more than λ, the expression in square brackets is positive so D increases r_i when it exceeds r_j and decreases it otherwise. In other words, the pairwise interaction drives i's religiosity further away from j's. The intuition is that j is a negative role model, and his lack of religiosity (or excessive religiosity) drives i to become more (or less) religious. On the other hand, if the two agents' religiosities differ by less than λ, then the interaction effect I brings them closer together. The idea behind the tolerance parameter λ goes back at least to the psychology literature on biased assimilation, e.g., Lord et al. (1979) reports evidence that people are more likely to be influenced by someone whose opinion is close to theirs, and they often reject opinions which are very far from their own.

The parameter $q \in [0, 1]$ in equation (1) governs the importance of pairwise interactions relative to peer group effects, to which we now turn.

3.3 Club Goods Parameters

The other term C in our simulation model is based on the club goods model of Iannacone (1992). The peer group (or "club") consists of all agents linked to the given agent; let Q be the link strength-weighted average of their religiosities. The model assigns to each agent the

utility function and budget constraint

$$U(r, S|Q) = [S^b + cr^{ab}Q^{(1-a)b}] \text{ s.t. } p_r r + p_s S = I. \tag{2}$$

Thus utility is a Constant Elasticity of Substitution (CES) function of secular activity S and religious subutility,[3] where the latter is a Cobb-Douglas function (with parameter a) of own religiosity r and the mean religiosity Q in the peer group. The substitution elasticity between S and religious subutility is $\eta = \frac{1}{1-b}$. Note that $\eta > 0$ for $b \in (0, 1)$ and $\eta \to \infty$ as $b \uparrow 1$. That is, secular and religious goods are imperfect substitutes for $b < 1$ and become perfect substitutes at $b = 1$. For $b > 1$ we see that $\eta < 0$, i.e., the two sorts of goods are anti-substitutable.[4]

The simulation normalizes nominal income $I = 1$, and considers changes in real income $Y = I/P$ by varying the price level $P = p_s$, holding constant the price ratio $p = \frac{p_r}{p_s}$. It also considers changes in the price ratio holding constant real income. Default values are $b = 0.8, a = 0.3, Y = I = 1, p_s = 1$ and $P = p_r = 0.6$.

The convention in equation (2) is that the budget constraint always binds, so we can write $S = \frac{I - p_r r}{p_s} = Y - pr$ and rewrite the payoff function (2) as

$$\phi(r|Q) = (Y - pr)^b + cr^{ab}Q^{(1-a)b}. \tag{3}$$

The peer group update C then is the scaled payoff gradient

$$C = 4(1 - q)\phi_r(r|Q) = 4(1 - q)[abcr^{ab-1}Q^{(1-a)b} - bp(Y - pr)^{b-1}]. \tag{4}$$

The update (4) thus captures the idea that agents adjust their religiosity incrementally to improve their sense of well being, taking into account the relative benefits of both secular activity and also (given their peer group) religious activity,[5] and also taking into account

[3] CES production functions raise the bracketed expression in (2) to the power $1/b$. That transformation is unnecessary here because, for the parameter values $b > 0$ used below, it is monotone increasing and so the resulting utility functions represent the same underlying preferences as U.

[4] Anti-substitutable means that compared to two distinct bundles of the goods that bring equal satisfaction, a middling bundle brings lesser satisfaction. More formally, if $U(X) = U(Y)$ for two bundles $X \neq Y$, then for any mixture $Z = mX + (1 - m)Y$ with $0 < m < 1$, we have $U(Z) < U(X) = U(Y)$ when $b > 1$. Of course, when $0 < b < 1$, we have the usual convexity property that $U(Z) > U(X) = U(Y)$, meaning that mixtures are preferred.

[5] In the simulations reported below, the variable c in equation (4) is tuned so that in equilibrium each player's religiosity r will equal Q, that of her peer group. See Appendix B for details.

the relative costs and their available resources. The factor 4.0 accounts for the way the logit function scales at midrange (where $r = 0.5$), and the factor $1 - q$ again reflects the importance of peer group update C relative to direct interpersonal influence D.

4 Results

We begin by showing the impact of varying key parameters one at a time from baseline values $N = 100, T = 4,000,000, K = 0.16, \beta = 0.05, b_d = -1, b_{sm} = 0, \lambda = 0.2, q = 0.8, a = 0.3, b = 0.8, I = 1, p_s = 1, p_r = 0.6$, and $\sigma = 0.0005$. Most of these have already been explained; here we note that (given the typical neighborhood size), $q = 0.8$ seems to roughly equalize the impact of the C and D effects, and noise level $\sigma = 0.0005$ seems sufficient to avoid meaningless stagnation while keeping negligible the impact of particular random realizations.

The figures in the next subsection report summaries of 40 Monte Carlo simulations for each parameter vector. The first panel plots the final (period T) means of each group with a small dot and their average across all 40 simulations with a large dot. The second panel plots the fraction of the simulations deemed fundamentalist and strictly fundamentalist.

4.1 Comparative Statics

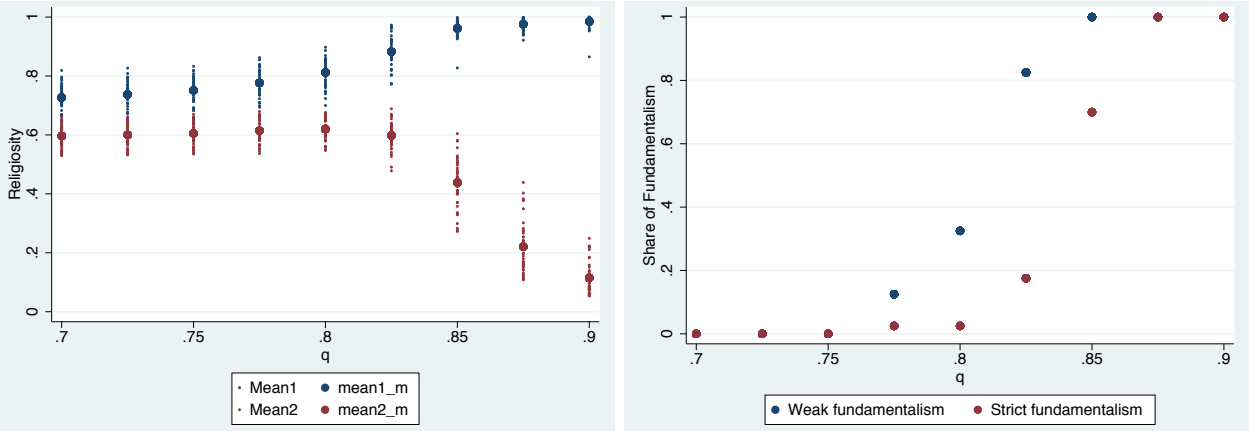

Figure 4: The impact of parameter q (weight of pairwise interactions) on mean religiosity in both groups (Panel A) and on the frequency of fundamentalism (Panel B).

Panel B of Figure 4 indicates that, near default values of parameters, the prevalence of fundamentalism is surprisingly sensitive to the balance between pairwise interaction and club goods. Increasing the weight q on pairwise interactions slightly, from its default value of 0.80 to 0.85, increases the fraction of Monte Carlo trials exhibiting strict fundamentalism from under 5% to over 70%, and increases the fraction F exhibiting (weak) fundamentalism from under 40% to nearly 100%. On the other side, when q is below 0.75, hardly any trials exhibit fundamentalism of either sort. Panel A shows how increasing q sharply increases bimodality, as the more religious group moves towards maximal religiosity, and the lower group towards atheism.

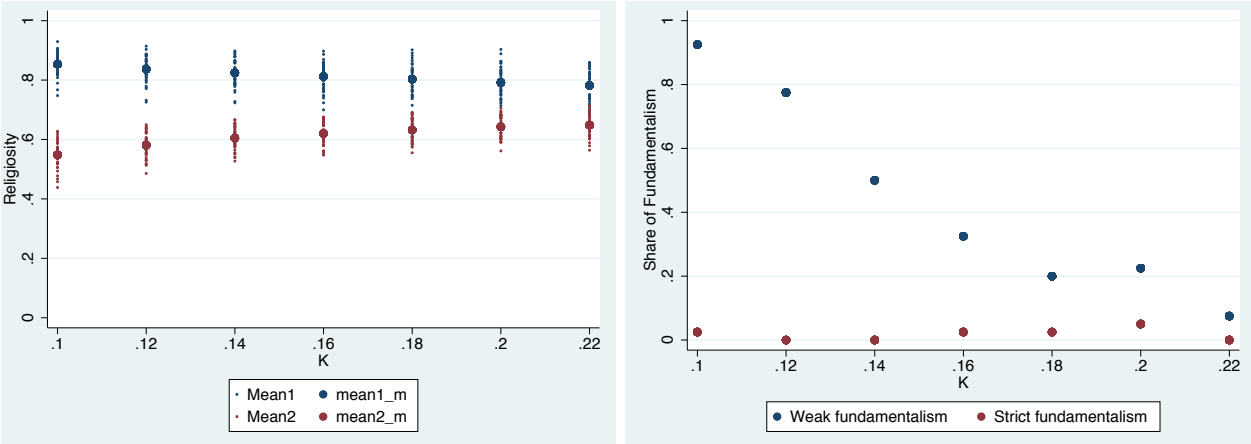

Figure 5: The impact of parameter K (neighborhood radius) on mean religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

Evidently, unless tempered by club goods effects, pairwise interactions tend to push towards polarization (hence fundamentalism) in our model with baseline parameters. To better understand that push, consider the impact of varying the typical size of a neighborhood. Figure 5 shows about half as much fundamentalism of either sort as the neighborhood radius K increases from the default value of 0.16 to 0.22, which corresponds to about $(.22/.16)^2 \approx 1.5$ times the area, i.e., about 50% more neighbors than in the baseline. Reducing K to .10 implies that a substantial fraction of the population has no neighbors, and thus retains its initial religiosity. The result is often a very diffuse final distribution which, as discussed just before Section 3.1, is classified as fundamentalist but not strict.

What is the impact of the long-distance rewiring parameter β? Default parameter values ensure that the long-distance links have about the same weight as the local links. Figure 6

shows that increasing the prevalence of long-distance links from 0 to 10% tends to reduce fundamentalism modestly.

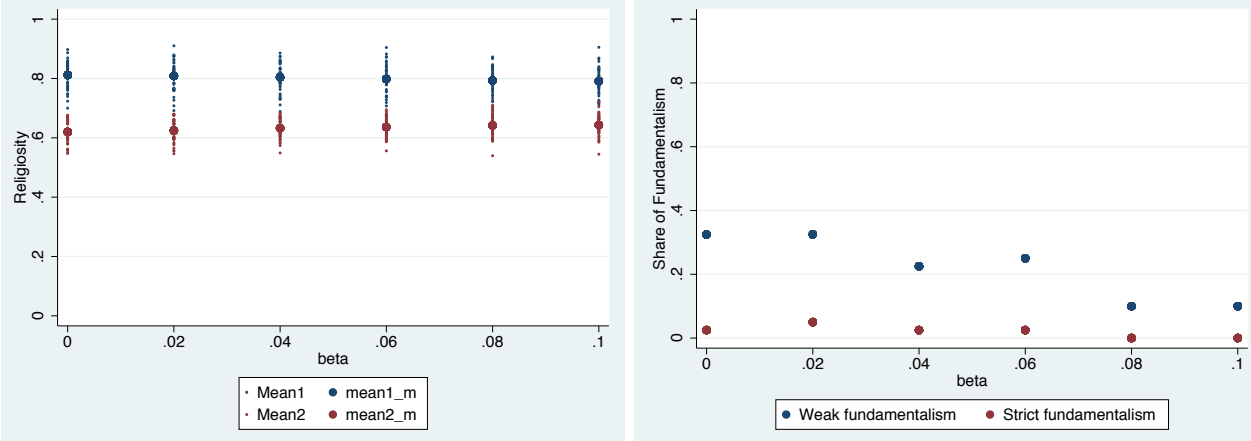

Figure 6: The impact of parameter β (probability of long-distance connections) on mean religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

The takeaway from the last two Figures is that increasing the number of neighbors (and to a lesser extent, including more distant links) decreases the prevalence of fundamentalism. Why might that be? Figure 7 shows that the tolerance parameter λ plays a major role. Recall that pairwise interactions tend to push neighbors' religiosity towards each other when λ is large, and indeed Panel A suggests mainly moderate (and unimodal) distributions when $\lambda > 0.5$ or so. With λ at its default value of 0.2 or less (and with not too many neighbors), however, we see more polarized distributions. This might help explain the q puzzle — the baseline pairwise interactions tend to be polarizing.

Turning to C-oriented parameters, we see from Figure 8 that fundamentalism of both sorts virtually disappears when the relative price $p = p_r/p_s$ is much above its default value of 0.6. Panel A shows the proximate cause: the religiosity distribution becomes unimodal and increasingly moderate. A deeper reason is the budget constraint: for p near 1, an agent with religiosity near 1 would have almost nothing left for secular goods, so the C term then would push group 1 members towards moderation. The impact of lower p is even more interesting — group 1 members can afford very high levels of religiosity, but in many (not all) trials group 2 members choose very low religiosity despite its affordability. As a result, fundamentalism is very frequent.

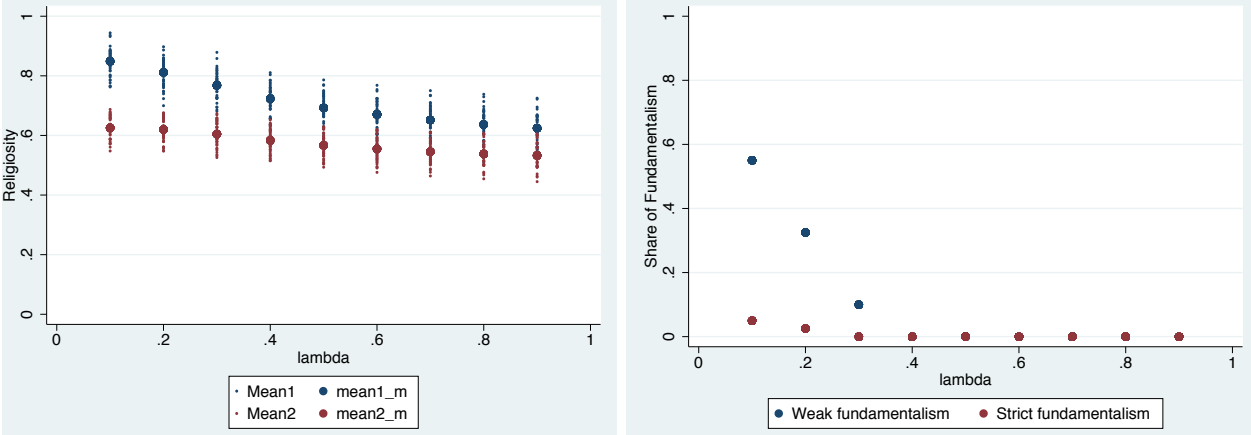

Figure 7: The impact of parameter λ (tolerance) on mean religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

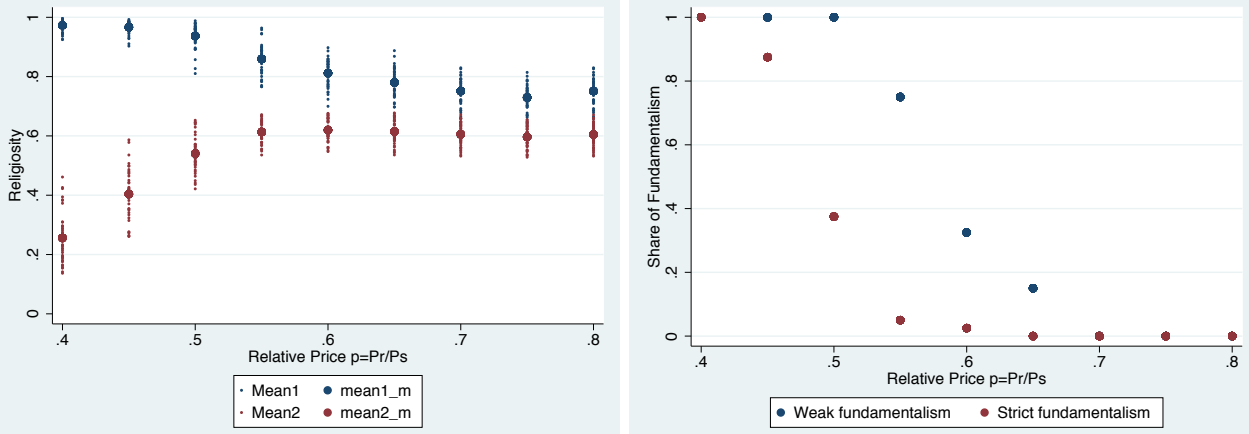

Figure 8: The impact of parameter p (relative price of religious goods) on mean religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

Figure 9 shows the impact of real income $Y = I/p_s$. Fundamentalism (and to a lesser extent, strict fundamentalism) increases for higher real incomes and decreases for lower real incomes. The proximate reason, seen in Panel A, is that lower income enforces a unimodal moderate distribution of religiosity; evidently poor people can't afford ostentation in religious (or secular) display, while polarizing forces have more room to operate at higher income levels.

Figure 10 shows that, when the CES parameter b is less than its default value of 0.8 (and other parameters are at default settings), there is again a tendency towards unimodal moderate religiosity distributions. The two group means are not far apart and the top mean is usually less than 0.8, so fundamentalism is rare. However, when $b > 1$, the population tends

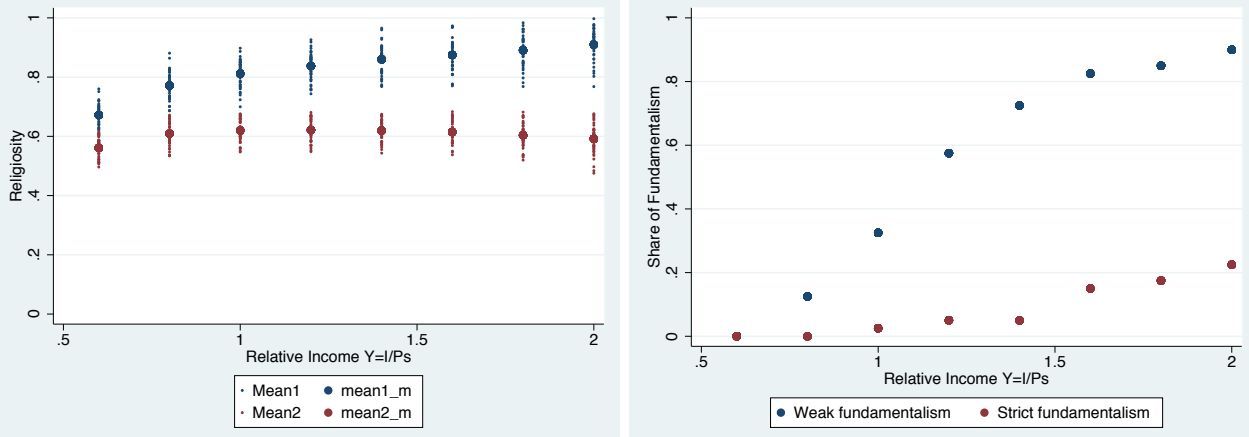

Figure 9: The impact of parameter Y (real income) on mean religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

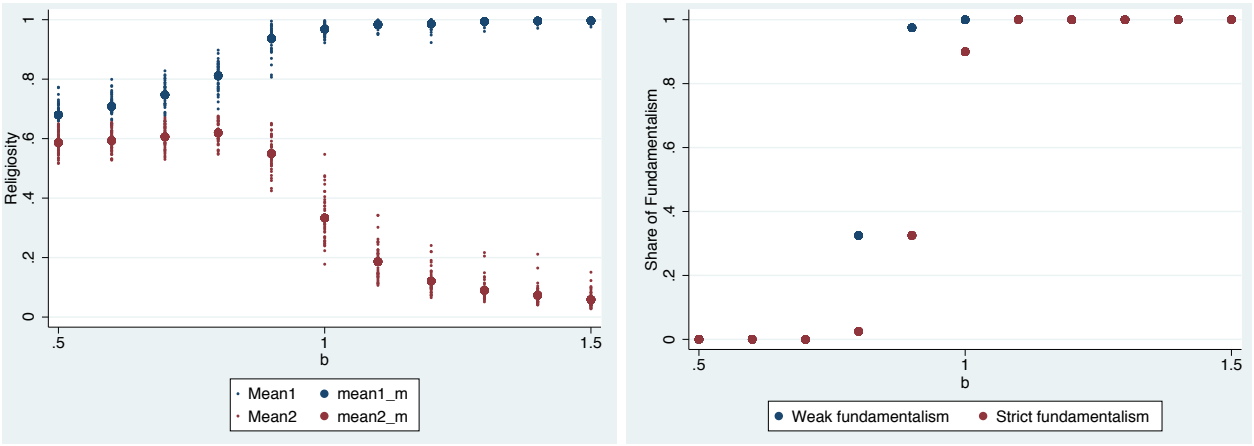

Figure 10: The impact of parameter b (substitutability of secular for religious goods) on mean religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

towards polarization, and most simulations are deemed fundamentalist ($F = 1$). We attribute this to anti-substitutability which, as discussed in Section 3.3, tends to push towards corner solutions. Panel A confirms the resulting extreme polarization.

Finally, Figure 11 shows the impact of the Cobb-Douglas parameter a in religious subutility. Higher a puts less weight on the peer group's average religiosity and more on own religiosity; we see much more fundamentalism when a increases much above its default value of 0.3. Evidently putting lesser weight on the peer group once again enhances polarization.

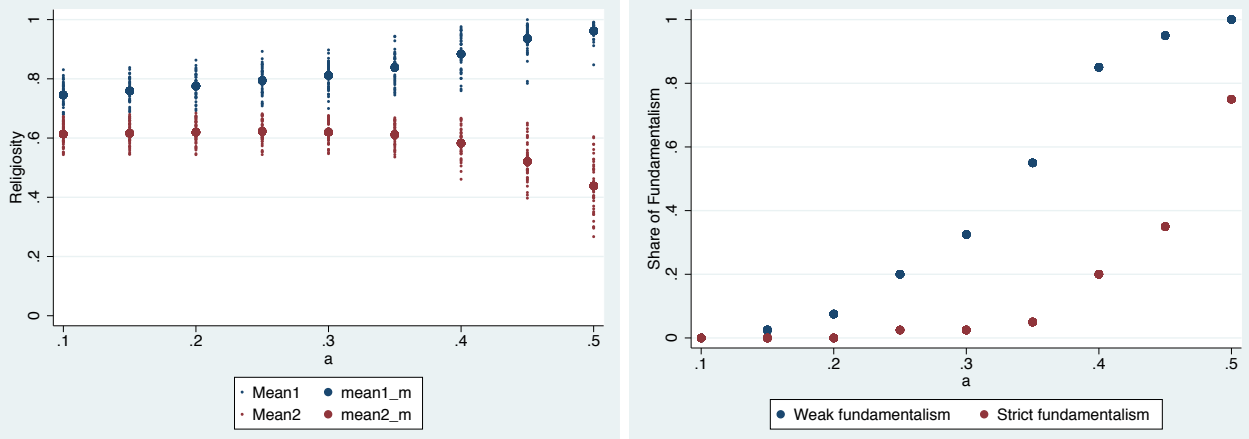

Figure 11: The impact of parameter a (weight on own (vs peer group) religiosity) on mean religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

4.2 Modernity

The baseline parameter values were chosen to illuminate how the model responds, and they perhaps best capture a world hovering between traditional society and modernity. To capture the transition to modernity, then, we consider shifts in the key parameters from values below baseline to values above it, or the reverse.

We begin with the standard economic variables, real income Y and relative price p. Unquestionably average real income is much higher in the modern world, and indeed is higher for most social strata. As we have seen, in our simulations an increase in Y from subsistence levels is quite conducive to the emergence of fundamentalism. The effect of modernity on the relative price $p = p_r/p_s$ is arguable; mass production and trade surely lower the price p_s of secular goods, but advances from Gutenberg's bible to televangelism and mobile messaging have also lowered the price p_r of religious goods. To the extent that the net effect is a decrease in p, we have an additional economic explanation for fundamentalism in the modern world.

Makowsky (2011, 2012) argues that increases in the substitutability between religious and secular goods will increase bimodality of the population, and increase the percentage of extremists. Our simulations confirm that the substitutability parameter b has those sorts of impact. Indeed, going a bit further, we argue that the modern world may be characterized by *anti-substitutability* ($b > 1$). The point is that it is harder than ever to mix religious

and secular education, and that the distinction has never been sharper between secular state provision and religious community provision of health care, disaster insurance and other public goods. We have seen that anti-substitutability gives fundamentalism a major boost in our simulations.

Has modernity shifted the tolerance parameter λ? We see cross-currents, with possible increases in some places offset by decreases elsewhere. Wherever the net effect is a decrease, we have yet another explanation for the emergence of fundamentalism.

Clearly the modern world has much improved communications technology and transportation. Long distance connections became much less exceptional during the 20th century, and "small world" is a widespread 21st century reality. So moving β from 0 to, say, 0.05 seems reasonable, and increasing the neighborhood size K can capture the direct impact. A surprising implication of our model is that neither of these shifts explain the emergence of fundamentalism in the modern world; if anything, they tend to discourage it mildly.

The indirect impact may be stronger. Some prominent observers (e.g., Putnam, 1995) have argued that the modern world weakens local groups, possibly as an indirect consequence of improved communications technology and transportation. Our simulations capture such loss of "social capital" via increases in parameters a (personal vs group subutility) and q (importance of pairwise interactions relative to peer group interactions). Increases in either of these parameters above baseline values greatly encourages fundamentalism.

5 Discussion

Why has fundamentalism become so prevalent in the modern world? Our approach to this question can be summarized briefly. We say that fundamentalism is present when there is a coherent minority of the population that is highly religious, and substantially more so than the majority. We compare the prevalence of fundamentalism across simulations of our model as we vary parameters defining pairwise interactions and peer group interactions.

The simulations suggest that several aspects of modernity may play an important role. The modern world is characterized by higher real income and lower "social capital," and the corresponding simulation parameters greatly boost fundamentalism. Modernity has made

secular and religious activities less complementary, and perhaps even "anti-substitutable," which again boosts fundamentalism. Other aspects of modernity are less clear in our simulation model. Tolerance and the relative price of religious vs secular goods are important drivers of fundamentalism, but it is hard to say which way modernity pushes them. Modernity clearly increases the potential span of personal networks, but the simulation does not suggest that those parameter shifts boost fundamentalism.[6]

The approach presented here can be extended in several respects. One can tweak the numerical expressions used to define fundamentalism, and the baseline parameters. Slightly more adventurously, one could replace the cutoff procedure for defining fundamentalism by estimating a two-group mixture model. The initial locations of agents need not be isotropic; there could be clusters to capture oceans or mountains or other natural barriers.

Simulations could also capture network dynamics, which for simplicity we have neglected. The link weights, and perhaps agents' locations, could be allowed to evolve, to capture the idea that most people prefer to associate with like-minded individuals. This increased complication regarding pairwise interactions probably would require streamlining, or perhaps even dropping, the peer interactions, but it might be worthwhile. Likewise, we have restricted our attention to a single religion, but more complicated simulations might consider the interaction of alternative faiths.

Thus we do not regard the present simulation model as the final word, but rather as an exemplar of a promising approach. In connection with other approaches, we hope that it gives new insight into many questions regarding the distribution of religious behavior within a population, including how and when fundamentalism can take root.

[6] In particular, increasing the "small world" parameter β tends to slightly *decrease* the prevalence of fundamentalism in our simulations, contrary to the conjecture of some of the authors. It remains to be seen whether this effect is reversed if, as suggested below, link weights are allowed to evolve.

Appendix A: Case Studies

A.1 Overview of the case studies

Originally, the term "fundamentalism" was coined to describe a group of theologically conservative American Protestants in the late 19th and early 20th century. It is thought that the term was first used in 1920 by Curtis Lee Laws, who was an editor of *Watchman-Examiner*, a conservatist Baptist publication. It was meant to describe those Protestants "who were ready to defend the fundamentals of the faith" (Hood et al. 2005). Since then, the term has often been used in the context of movements in other parts of the world in other periods of time, such as Iran after the 1979 revolution and India in the 1990s.

As part of the present project, we have conducted case studies of four movements which can be described as "fundamentalist." We now briefly outlines each of them in terms of doctrine, history, and distinctions from other movements.

1. Protestant fundamentalism in the United States

This movement developed in the United States from around 1870 to 1925 (Emerson and Hartman 2006). The main characteristic of Protestant fundamentalists is their belief in the inerrancy of the Bible in all aspects, including the creation of the world, the virgin birth of Jesus Christ, and the promise of his eventual return. These and other central beliefs were outlined in a series of essays entitled *The Fundamentals: A Testimony to the Truth*, which were published between 1910 and 1915 (Hood et al. 2005). It was this title which later helped establish the terms "fundamentalism" and "fundamentalists". The movement began to lose on importance from 1925 when the American Protestant fundamentalists were humiliated in the famous trial of John Scopes, a young biology teacher who was accused of teaching evolution in schools in Tennessee (Marty and Appleby 1991). Woodberry and Smith argue that only a small part of today's conservative Protestants in the US can be described as "fundamentalists." Instead, as Hood et al. (2003) writes, many conservative Christians in the US use the term "evangelicals" to describe themselves, and most academics agree that "fundamentalists" and "evangelicals" constitute two different groups, despite some similarities.

2. Islamic fundamentalism

Defining "fundamentalism" in the context of Islamic religion is problematic because the belief in inerrancy of the Muslims' sacred text, the Quran, is not a good criterion. The reason is that, as Ruthven (2012) points out, "virtually all believing Muslims — not just those described as 'fundamentalists' — see the Quran as the eternal unmediated Word of God." Lewis (1998) argues that Islamic fundamentalists "base themselves not only on the Quran, but also on the Traditions of the Prophet, and on the corpus of transmitted theological and legal learning." Fundamentalism in the Sunni branch of Islam developed for example in Egypt. As Marty and Appleby (1991) write, the beginnings of modern fundamentalism in Egypt can be traced back to the first decades of the 20th century and to the establishment of the Muslim Brotherhood in 1928. The Muslim Brotherhood was one of the sources of members for the Egyptian fundamentalist movement, which was still rather weak during the presidency of Gamal Abdel Nasser in the 1950s and 1960s. The movement grew in power in the 1970s under Anwar Sadat's presidency and in the 1980s. The assassination of Sadat by fundamentalists in 1981 is often seen as a symbol of Islamic fundamentalism in Egypt (Marty and Appleby 1991). Fundamentalism in another branch of Islam – Shi'ism – developed in Iran as a reaction to secularization under the reign of Reza Shah Pahlavi (Almond et al. 2003) and grew rapidly after the Iranian revolution in 1979 under the charismatic leadership of Ayatollah Khomeini. It should be mentioned that there are also other terms which are often used in similar contexts to "Islamic fundamentalism," e.g., "Islamism", "political Islam", and "militant Islam" (see Kramer (2003) and Sonn (2006)).

3. Hindu fundamentalism in India

The movement is represented by two non-governmental organizations: the RSS (Rashtriya Swayamsevak Sangh) and the VHP (Vishna Hindu Parishad), as well as by a major political party - the BJP (Bharatiya Janba Sangh), which is closely linked to the RSS. Hindu fundamentalism differs from Abrahamic (i.e. Jewish, Christian, and Islamic) fundamentalisms in that there is no unified scripture, inerrancy of which members could believe in. However, the book Hindutva, written by Vinayak Savarkar, the leader of the RSS, and published in 1922, provides a doctrine for Hindu fundamentalists in a similar way to the Bible for Christians or

the Quran for Muslims. The book describes the concept of "Hindutva" ("Hinduness") which "defines the geographic, racial, and religious boundaries of Hinduism" (Almond et al. 2003). Hindu fundamentalism's origins can be seen in nineteenth-century movements like Brahmo Samaj and Arya Samaj (Keddie 1998). The movement grew rapidly in the 1980s, which is shown by an increase in active membership in the RSS from 1,000,000 in 1979 to 1,800,000 in 1989 (Marty and Appleby 1991). The BJP party won the largest number of seats in the Indian parliament for the first time in 1996. Despite a decline in popularity in the 2000s, it won over 51 percent of seats in the 2014 elections.

4. Pentecostalism in Latin America

There is no consensus whether Pentecostalism is a "fundamentalism". It is undoubtedly a distinct movement from the original Protestant fundamentalism but it has several characteristics of a fundamentalist movement, including the belief in inerrancy of the scripture (i.e. the Bible). Hood et al. (2005) mention that some Pentecostals even describe themselves as "fundamentalists". What makes Pentecostals different from the original Protestant fundamentalism is that the former attach more importance to the direct experience of God through the Holy Spirit, which takes the form of, for example, speaking of tongues, healing, and prophesying (Robbins 2004). Put briefly, "fundamentalists emphasized doctrine; Pentecostals - experience" (Woodberry and Smith 1996). Pentecostalism emerged at the beginning of the 20th century from the Holiness movement, which was a branch of evangelicalism (Woodberry and Smith 1996). The so-called Asuza Street Revival in 1906-1909 (i.e. the preaching by William Seymour in an abandoned church on Asuza Street in Los Angeles) is considered by scholars as the birth of Pentecostalism (Robbins 2004). Currently, Pentecostalism is growing rapidly in many parts of the world, especially Latin America and Africa.

A.2 Characteristics of religious fundamentalism

In this section we aim to summarize the main characteristics of movements which can be described as "fundamentalist". This analysis is based on Almond et al. (2003), Emerson and Hartman (2006), and our case studies of four fundamentalist movements. It should be

emphasized that this list is not exhaustive; however, most of the fundamentalist movements share the vast majority of these characteristics, if not all.

1. Belief in inerrancy of scripture. Fundamentalists believe that their scripture has divine origin and is true in all aspects (Almond et al. 2003). This refers to sacred texts such as the Bible for Christian fundamentalists and the Quran for Islamic ones, but also to the "Hindutva" for Hindu fundamentalists.

2. Reaction to modernity and secularization. The emergence of fundamentalism is often considered a response to modernity and secularization. For example, the Protestant fundamentalism in the US is said to have emerged "in reaction to rapid urbanization and industrialization, the spread of secular education and science, the decline of belief in sacred texts and religious tradition, and attenuating religious discipline" (Almond et al. 2003). Sunni fundamentalism in Egypt grew as a response to secularization efforts of Nasser in the 1970s, whereas the Shi'ite fundamentalism in Iran was largely triggered by rapid secularization under the reign of Reza Shah Pahlavi.

3. Unwillingness to compromise. Fundamentalists are often unwilling to compromise not only on religious issues but also on the secular ones. This is connected with the belief in inerrancy of the scripture. For example, the Quran and the Shari'a law are seen by Islamic fundamentalists as rules which cover all areas of life and cannot be changed regardless of the circumstances.

4. Separatism. It is a standard practice of fundamentalists to set sharp boundaries between members and non-members. This dualistic worldview is an important feature of, for instance, the "Hindutva": everyone who acknowledges ties to ancient India is included in the movement (even Sikhs, Jains, and untouchables), but Christians and Muslims are considered enemies (Keddie 1998). For Islamic fundamentalists, it is the Western culture in general which is seen as an enemy.

5. Millenialism and messianism. Many fundamentalist movements believe that the world will have a miraculous and positive end. The end will be accompanied by a golden age of 1000 years (hence "millenialism") and by the coming of a Messiah (hence "messianism"). This is particularly characteristic of Abrahamic religions (Almond et al. 2003).

6. Behavioral requirements. Members of fundamentalist movements are required to

follow specific behavioral requirements in various domains, such as worship, dressing, and eating. There are plenty of examples of such requirements, e.g., prohibitions on certain foods in Islam and the requirement to tithe and give offerings in Pentecostalism.

7. Militancy and active evangelization. Fundamentalists often engage in active evangelization (e.g., Protestant fundamentalists in the US and Pentecostals), which can even be considered as militant. However, this militancy does not necessarily mean that violence is being used.

8. Authoritarian organization and charismatic leadership. It is common for fundamentalist movements to have a more authoritarian structure than other religious movements and that they are centered around a charismatic figure. The leader can be more global (like Ayatollah Khomeini for Islamic fundamentalists) or more local (like local preachers in Pentecostal churches in Brazil).

9. Provision of social life and welfare services. Fundamentalist movements strive to provide benefits for their members, which can take various forms, such as building schools (e.g., by Protestant fundamentalists in the US) or even simply organizing regular occasions for group life (e.g., neighborhood meetings in the RSS in Hindu fundamentalism and exuberant worship services in Pentecostalism).

10. Alienation from the rest of the society. Alienation of fundamentalists from the rest of the society arises mainly for two reasons. First, new members are often drawn from isolated subpopulations by offering them better life. In most cases, this refers to lower classes of the society (e.g., in Pentecostalism), but in the case of Iran it was the educated young middle class that was alienated by the modernization and secularization program of Reza Shah Pahlavi and subsequently attracted by Sunni fundamentalists. Second, the alienation is a result of the already mentioned practice of setting sharp boundaries between members of the movement and the others.

A.3 Changes associated with modernity

It is often asserted that fundamentalist movements have emerged as a response to modernity. In this section, we describe in more detail the changes which have been associated with

modernity and we highlight the impact of each of these changes on the parameters of the model.

1. Decline of social capital

Modernity has brought significant changes in the society. It has been argued that there has been a significant decline in the social capital over the last few decades. The most influential work on this is Robert Putnam's 1995 essay *Bowling Alone: America's Declining Social Capital* and his 2000 book *Bowling Alone: The Collapse and Revival of American Community*.

In his works, Putnam studied the changes to the social capital in the United States based on over 500,000 interviews over 25 years. He found that fewer and fewer people belong to civic organizations and that people know their neighbors less and meet with their family and friends less often. Another finding is that there are now fewer people who bowl in leagues because more and more people tend to choose to bowl alone, which inspired the titles of Putnam's works. He offers several potential explanations for these changes: suburbanization leading to more time spent by people on travelling than on social activity, changes in the family structure such as a higher number of single and childless people, and the technological transformation of leisure leading to the "individualization" of leisure.

The decline in social capital can be understood as decline in engagement of people in social groups. Therefore, as far as the model is concerned, this could be interpreted as a decrease in the weight that people attach to club interactions, i.e. an increase in the value of parameter q. It could also imply an increase in the Cobb-Douglas parameter a for

2. Progress in communication and transport technology

Over the last 200 years, the world has witnessed an unprecedented progress in communication and transport technology. Communication was revolutionized in the 19th century by the inventions of the electrical telegraph and the telephone. In the 20th century, radio and television developed and became widespread around the world. Finally, the last few decades saw rapid development of mobile phones and the Internet. The Internet usage increased

from 11% in 1997 to 81% in 2016 of the developed world population and from 2% in 1997 to 47% in 2016 of the global population.[7] This was accompanied by extensive growth of media, including the so-called social media such as Facebook and Twitter. The progress in transport technology has been similarly impressive over the last 200 years. It included the development of trains, automobiles, and planes, and their widespread usage around the world.

The developments in communication and transport undoubtedly improved the flow of information over long distances and increased the amount of interaction between people from distant parts of the world. In terms of the model, these developments have led to changes in the network. More precisely, the number of long-distance links has grown, i.e. the values of parameters K and β have increased.

3. Increase of wealth and improvement of living standards

An important aspect of modernity is the general increase of wealth and improvement of living standards around the world. The 20th century witnessed unprecedented growth in real global GDP: it rose about 19-fold, which corresponds to an average annual rate of growth of 3 percent (IMF World Economic Outlook 2000). At the same time, living standards have been raised to a great extent, mostly thanks to technological and economic changes. Many indicators of well-being have improved such as life expectancy and education (IMF World Economic Outlook 2000). Poverty has also been reduced significantly. The proportion of global population living for under 1.90$ per day (2011 PPP) has decreased from over 42% in 1981 to less than 11% in 2013.[8] The number of people living in low human development fell from 3 billion in 1990 to slightly more than 1 billion in 2014 (Human Development Report 2015).

It is important to note that the income parameter in the model can have a more general interpretation than just monetary wealth. It can be conceived of as the amount of resources (such as money or time) that they can devote to secular and religious activities. Yet, given the significant rise of the monetary wealth around the world in the 20th century, it can be argued the value of the parameter describing an agent's real income, Y, has also increased.

[7] International Telecommunication Union data.

[8] World Bank data: http://data.worldbank.org/topic/poverty.

4. Growth of secular opportunities

It can be argued that modernity has increased the richness of secular opportunities. Progress in communication technology brought many new ways to spend time in a secular way, e.g., the entertainment industry has grown extensively. Progress in transport technology has opened many new opportunities by increasing the mobility of people. As a result, tourism has developed greatly over the last century and many new secular professions were created that involve travelling. It should be noted that these changes have also brought new religious opportunities. For example, development of new media has allowed people to participate in religious services by watching them on television and to interact with other members of their religious groups via the Internet. Easier transport has made pilgrimages to holy places easier. However, overall, progress in communication and transport has likely increased the richness of secular opportunities to a significantly greater extent than the richness of religious opportunities. Another aspect that brought new secular opportunities is secularization imposed by the state, which happened in many places of the world, e.g., in Turkey under Mustafa Kemal Atatrk or Iran under Reza Shah Pahlavi (Marty and Appleby 1991).

The growth of secular opportunities means that secular activities have become relatively more easily accessible to people than religious activities. One way of interpreting this is to say that the relative price of religious activities versus secular activities has increased, i.e. $p = p_r/p_s$ has increased.

5. Growing incompatibility of religious and secular activites

Religious activities are becoming less compatible with the demands of secular activities. For example, educating children, observing holidays, and assisting those in need are examples of activities that traditionally combine religious and secular motives, but in the modern world these activities tend to occur in separate spheres.This is partly because religious behavioral requirements are becoming more difficult to satisfy, especially given the variety of new secular opportunities. Some of the requirements that concern participation in the religion (through contribution of time or money) can make it difficult to reconcile religious and secular activities. For example, Pentecostals are required to participate in services and to tithe, Muslims are required to pray, give alms and, if they can afford it, make a pilgrimage to

Mecca. Moreover, religion often requires its members to follow certain rules that cover many aspects of secular life, which again makes religious and secular activities difficult to reconcile. For example, Muslims need to fast during the Ramadan, follow the Shari'a law as well as many rules specified in the Quran, including prohibitions on certain foods, a number of legal rules concerning family law, criminal law, and commercial regulations (Ruthven 2012).

Another channel through which the incompatibility of religion and the modern world increases is secularization, which has been imposed by authorities in many parts of the world. An example of such imposed secularization is Iran under the reign of Reza Shah Pahlavi, whose policy concentrated on de-emphasizing the Islamic component in education and other domains (Marty and Appleby 1991). Secularization inevitably leads to a greater role of secular activities in people's lives (e.g., secular education), which may be difficult to reconcile with continued engagement in religion.

Overall, there seem to be several reasons to argue that religious activities are increasingly becoming less compatible with secular activities in the modern world. As far as the parameters of the model are concerned, this would translate into anti-substitutability between religious and secular activities, i.e. the value of parameter b could be driven above 1.

Appendix B: Code description

The model is implemented in C++ and we describe the operation of the code here.

Inputs

As inputs the code takes two or three data files, plus several parameter values.

- The first data file specifies the initial state of the network, i.e., the initial religiosity levels, $\{r_i\}$, of the agents in the network.
- The second input file contains the various model parameters: q (weighting for pairwise interactions versus club); λ (parameter characterising pairwise interaction); a,, b, p_r,

p_s (parameters characterising club good interaction) and σ (standard deviation of the noise term).

- The third optional input data file is the description of the network. This is a list of node pairs plus weights describing the links that exist in the network and the relative probability of an interaction occurring. If this file is omitted the code assumes we want to use a completely connected network, i.e., every node has a link to every other node and these links are all equally weighted.

- In addition, the user provides the name of an output data file, the number of iterations (model updates) to perform and a random seed that will be used to initialise the random number generators required for the probabilistic model updates to ensure reproducibility of the results. The user can also optionally supply the value of the distance weighting parameter, b_d, used to specify the strength of the network links.

Variables

As the model runs, various network properties are tracked. These include the network characteristics, i.e., all the links that exist in the network and their weights. In the simulations described in this article, the network characteristics do not evolve over the simulation, but the code supports that capability. The code also tracks various properties of each node. This includes their current religiosity, the location of their neighbours and the average religiosity of their neighbours, used as the parameter Q in the club-good part of the update model. The code also has the capability to support heterogeneous networks, with different values of the model parameters, such as λ, a, b, p_r and p_s, for each agent, but again that feature was not used for the results reported in this article. The code also keeps track of various average properties of the network.

Code operation

The code structure is as follows.

- **Initialisation:** on starting the code performs various initialisation operations

- Read parameters from the command line.
- Read parameters describing the model from the model parameter file and initialise the corresponding variables in the model.
- If a network file is provided, read the network description from the file and create the network array structures to store the details. If not, generate network structures describing a completely connected network.
- Create the arrays for storing the node properties. Read in the initial states of the nodes from the input file and initialise the arrays.
- Opens files for output.
- Compute mean properties of the network and derived node characteristics, such as the mean religiosity of neighbours for each node, as per the particular model specification. Create arrays for storing network and node characteristics and initialise.

- **Iteration:** after initialisation the code performs the number of iterations specified by the user. This was $T = 4,000,000$ for the runs described in this article. On each iteration the code performs the following steps
  - Choose a link in the network at random, with weighting according to the current weights of the various network links. This specifies the two nodes that interact at this iteration and a direction, i.e., which node is "A" and which is "B". After the interaction, only the religiosity of A changes, but the size of the change depends on the states of both A and B and the average state of neighbours in the network.
  - Update the religious adherence of Node A according to the interaction model described in Sections 3.2 and 3.3. This is a combination of the direct interaction, D, given in Eq. (1), the club good interaction, C, given by Eq. (4), and the normal noise term, n. These give the update to the logit-transformed religiosity of agent A, which is then converted to the new religiosity of the agent. Note that the club good update depends on the mean religiosity parameter, Q, which is computed as a weighted average over all nodes linked to agent A, with weights equal to the weights on the corresponding legs of the network.

- Update the mean field parameters and derived node characteristics based on the new state of the network.
- Write new state of network to output files.

The code runs for the specified number of iterations and then the files are post-processed to compute the quantities required to assess if the final state of the network meets the criteria for Fundamentalism as defined at the start of Section 3.

The parameter c that enters the club good utility function, Eq. (2) was not specified in the body of the text. This parameter affects where the maximum utility appears for a given mean field religiosity, Q. The club good model pushes agents towards conforming to the mean, but if the parameter c is set to 1 as in Iannacone (1992), the maximum utility does not occur at $r = Q$. The effect of this in simulations was that, in the absence of the direct interaction term, the network would homogenise, but then the religiosity of all the nodes would drift over subsequent iterations of the network. This was deemed to be an undesirable feature and so we introduced the parameter c which was fixed to ensure that the maximum utility occurs at $r = Q$. Solving the relevant first order condition, we obtain

$$c = \frac{p_r}{a p_s} \left[\frac{I - p_r Q}{p_s Q} \right]^{b-1} . \tag{5}$$

This value of c was used in all simulations described in this paper.

Appendix B.2: Supplementary Simulations

The reported simulations rather arbitrarily fix the number of agents at $N = 100$. To check robustness of our results to that choice, we ran simulations with other values of N as shown in Figure 12. We vary K so as to hold constant the expected number of neighbors,[9] and vary T proportionately with N so as to keep roughly constant the average number of updates of each agent.

[9]The expected number of neighbors is given by $N(1 - \cos(\frac{\pi K}{2}))$, the relative spherical area times the number of agents; with default values $N = 100, K = 0.16$ this implies just over 3 neighbors on average. The simulations vary K inversely with N so as to keep that number constant.

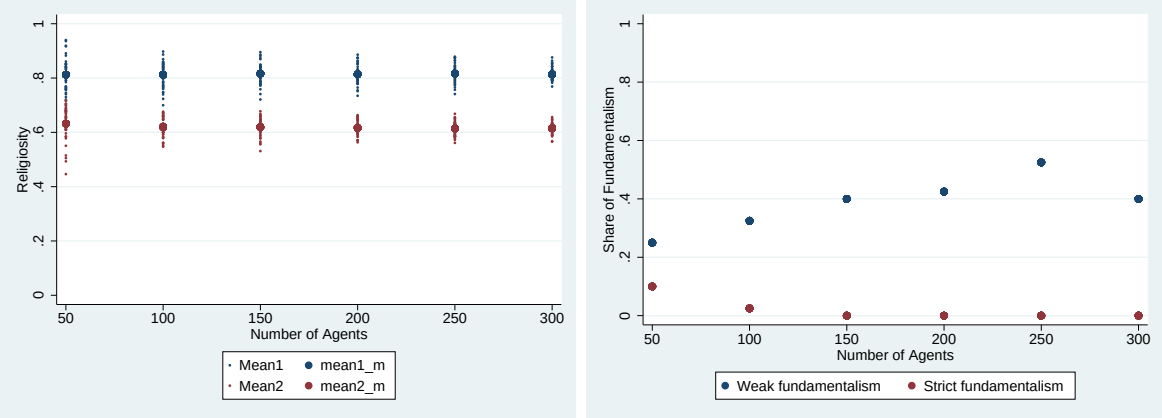

Figure 12: The impact of parameter N (number of agents) on mean religiosity (Panel A) and on the frequency of fundamentalism (Panel B), holding constant the expected number of neighbors.

Panel A shows only trivial impact on mean religiosity in both groups. Panel B shows a modest rise in the fraction of simulations deemed (weakly) fundamentalist and a modest decline in the fraction deemed strictly fundamentalist. this is more likely due to the random fluctuations, as we can see that the average mean of upper and lower group does not vary. We attribute this to slightly more dispersion around the means with larger N, possibly due the larger (absolute) number of individuals with weak links that are seldom updated. However, we do not see any systematic changes in the way religiosity evolves in simulations with $N > 100$.

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