A Simulation Study of How Religious Fundamentalism Takes Root*

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Abstract

Religious fundamentalism is observed across the world. We investigate its roots using agent-based simulations of religiosity dynamics in a spatially dispersed population. Agents' religiosity responds to neighbors via direct interactions as well as via club goods effects. A simulation run is deemed fundamentalist if the final distribution contains a cohesive subset of agents with very high religiosity. We investigate whether such distributions are more prevalent when model parameters are shifted to reflect the transition from traditional societies to the modern world. The simulations suggest that the rise of fundamentalism in the modern world is aided by weaker attachment to the peer group, greater real income, and less compatibility between religious and secular goods, and arguably also by higher relative prices for secular goods and lower tolerance. Surprisingly, the current model suggests little role for the rise of long-distance communication and transportation.

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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 vocal (and in some cases, violent) groups 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 Buddhists 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 such as the recently formed Taliban government in Afghanistan, 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. The present paper seeks initial insight from a simulation model.

Simulations complement but do not substitute for other approaches. The researcher builds known features into the simulation and looks for emergent behavior that, although perhaps unexpected at first, can on reflection improve intuition about how the known features interact. Simulations are appropriate here because we want to consider a wide range of possible answers to our questions. We hope that our results will help future work focus more sharply on narrower ranges of answers that are amenable to other approaches, including case studies, econometric analysis of historical data, and analytical models.[1]

Our simulation model traces the "religiosity" of individual agents over time in a spatially dispersed population. The agents interact directly with others and also within peer groups.

[1]Some simulation models, e.g., those used by the weather service or by some central banks, are intended to produce quantitative short-run predictions. Since we are concerned with phenomena that do not yet have such well established theory and empirics, our aim is less ambitious: to gain some qualitative long-run insight.

In the direct interactions, the agents are intolerant of those with very dissimilar religiosity and so their religiosity moves even further apart, but it moves closer together when agents with sufficiently similar religiosity interact. This similar/dissimilar feature is motivated by the psychology literature dating back at least to Lord et al. (1979). The peer group interaction features are motivated by club goods models in the tradition of Iannaccone (1992); the basic idea is that people who contribute to a religious community also benefit from the contributions of other members.

As a result of both sorts of interaction, the distribution of agents' religiosity evolves over time. We run simulations long enough for the distribution to settle down. The long-run distribution is deemed fundamentalist if, roughly speaking, it contains a cohesive subset of agents with very high religiosity.

We seek to investigate the following question: **How may modernity have led to the emergence of fundamentalism?** The simulation model therefore includes parameters that can capture aspects of the transition from traditional to modern societies, including (i) the decline of social capital, (ii) the progress in communication and transport technology, (iii) the increase in income, (iv) the growth of secular and religious opportunities, (v) the growing incompatibility of religious and secular activities, and (vi) the changes in tolerance. The objective of the simulations is to analyze how shifts in such parameters can affect the prevalence of fundamentalism.

We find that changes commonly associated with modernity such as the decline of social capital, the increase in income, and the growing incompatibility of religious and secular activities contribute to the emergence and growth of fundamentalism. To the extent that modernity may have led to a relatively greater growth of secular opportunities in comparison with religious ones and to a decline in tolerance, these changes would also help explain the greater prevalence of fundamentalism. Surprisingly, we find that the progress in communication and transport technology (reflected in a greater role of longer distance connections in the population) does not have a significant impact on fundamentalism in our model.

Section 2 discusses the notions of religious fundamentalism and modernity, and how they are captured in the simulation model. Section 3 reviews the related literature. Section 4 introduces the simulation model. Section 5 presents simulation results showing the comparative static impact of the key parameters that correspond to the changes associated

with modernity. Section 6 summarizes the insights gleaned from the exercise, and suggests future research directions. An online appendix contains more details on the simulation and supplementary results.

2 Introducing Religious Fundamentalism and Modernity into Simulations

The objective of this paper is to study whether and how modernity can affect the emergence of religious fundamentalism. Therefore, it is appropriate to first explain the notions of religious fundamentalism and modernity, and how we approach them in our simulations.

2.1 What Is Religious Fundamentalism and How We Approach It in Simulations

It would be desirable to begin with a generally accepted operational definition of fundamentalism, but there is considerable debate about what fundamentalism really is. Iannaccone (1997) notes that even the multi-volume *Fundamentalism Project* by Marty and Appleby (1991) provided no clear definition of fundamentalism nor objective criteria for categorizing religious movements as fundamentalist or non-fundamentalist.

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 Islamic fundamentalism, in particular in Iran after the 1979 revolution, and Hindu fundamentalism in India from the 1980s. Consequently, there are two ways of understanding "fundamentalism": in a narrow sense and in a broad sense. A narrow definition of "fundamentalism" refers only to the original Protestant movement in the United States. Proponents of the broader definition apply it to movements in other religions as long

as they share the same or similar characteristics, in particular a strong belief in the central tenets ("fundamentals") of the faith.

We conducted case studies of four movements which can be described as "fundamentalist" and briefly outline each of them in terms of doctrine, history, and distinctions from other movements in online Appendix B. The four movements that we outline include (i) the Protestant fundamentalism in the United States, which developed from around 1870 to 1925 and whose main characteristic is the belief in the inerrancy of the Bible in all aspects, (ii) Islamic fundamentalism, which grew up in particular in Iran as a reaction to secularization under the reign of Reza Shah Pahlavi and then after the Iranian revolution in 1979 under the leadership of Ayatollah Khomeini, (iii) Hindu fundamentalism in India, which is based on the concept of "Hindutva" and grew rapidly in the 1980s, and (iv) Pentecostalism in Latin America, which is growing rapidly and whose characteristics include the belief in the inerrancy of the Bible but also importance of a direct experience of God.

For the purposes of our simulation model, we distill the more complex aspects of fundamentalism down to two key characteristics, which relate to the level of religiosity.

First, fundamentalists have a very 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. Fundamentalists believe that their scripture has divine origin and is true in all aspects (Almond et al. 2003). This refers to sacred texts suchas the Bible for Christian fundamentalists and the Quran for Islamic ones, but also to the "Hindutva" for Hindu fundamentalists. Fundamentalists are often unwilling to compromise not only on religious issues but also on the secular ones. 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.

Second, fundamentalists form a relatively cohesive group in terms of the level of religiosity. This cohesion is typically achieved by introducing a set of behavioral requirements — e.g., for worship, attire, and diet — for the members. 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. Furthermore, a sharp boundary is usually set 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. These practices often result in the alienation from the society.

We operationalize this qualitative definition for our simulation model in Section 4.1. Whilst our definition captures what we consider the most salient characteristics of religious fundamentalism which concern the level of religiosity, it naturally cannot capture all possible characteristics.[2] We also note that two further characteristics of religious fundamentalism are not included in the definition but are endogenised in the simulation model: first, fundamentalist movements often provide social and welfare services,[3] which is embeded in the simulation model through the so-called peer group (or the "club good") interactions between agents, and second, it is often proposed that fundamentalist movements emerge as a reaction to modernity,[4] which is exactly the question that we analyse in our simulation model by including a number of parameters that correspond to changes associated with modernity. We turn to the notion of modernity and the changes associated with it in the next subsection.

2.2 What Is Modernity and How We Approach It in Simulations

Some authors speculate that fundamentalist movements emerged in response to modernity. For example, the Protestant fundamentalism in the US is said to have emerged "in reaction

[2]For example, it is common for fundamentalist movements to have a more authoritarian structure than other religious movements and to be centered around a charismatic leader. Fundamentalists also often engage in active evangelization (e.g., Protestant fundamentalists in the US and Pentecostals). Furthermore, many fundamentalist movements believe that the world will have a miraculous and positive end and will be accompanied by a golden age of 1000 years (so-called "millenialism") and by the coming of a Messiah (so called "messianism"). These features are beyond the scope of our simulation model.

[3]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).

[4]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 triggered by rapid secularization under the reign of Reza Shah Pahlavi.

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).

Before analyzing such claims, we first should clarify what we mean by modernity, and how it is to be represented in our simulations. The simulations hold constant a set of exogenous parameters that represent the ambient social environment, and they track the evolution of agents' religiosity against that constant backdrop. For us, modernity refers to a large and interconnected set of modifications to traditional societies. Our approach is to run some simulations with a vector of exogenous parameters intended to represent aspects of traditional society, and compare them to other simulations that use modified exogenous parameters intended to represent aspects of the modern world.

We now list and discuss the changes associated with the transition to modernity that our simulations seek to capture.

1. Decline of social capital. This process was famously studied by Putnam (1995, 2000), who found that at the end of 20th century that there has been a significant decline in the social capital over the previous few decades. Putnam (1995) himself defines social capital as the "the features of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit".[5] Drawing on more than half a million interviews in the US conducted over 25 years, he found that fewer and fewer people belong to civic organizations, people know their neighbors less well, and meet with their family and friends less often. Putnam 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. More recent work is generally consistent with Putnam's findings and provides a more nuanced perspective.[6]

[5]In an essay on social capital from the perspective of an economic theorist, Sobel (2002) defines social capital as "circumstances in which individuals can use membership in groups and networks to secure benefits", whereas the OECD defines it as "networks together with shared norms, values and understandings that facilitate co-operation within or among groups" (see Brian (2007)). For further discussion of various definitions of social capital, see for example Iyer, Kitson and Toh (2005).

[6]For example, McPherson, Smith-Lovin and Brashears (2006) find that most peer groups consist of rather

2. Progress in communication and transport technology. Over the last 200 years, the world has witnessed an unprecedented progress in transport technology, with the advent and global expansion of steamships, railroads, automobiles and airplanes. Communication was revolutionized in the 19th century by the inventions of the telegraph and the telephone. The early 20th century inventions of radio and television became widespread globally by the late 20th century, and since then mobile phones and the Internet have become ubiquitous.[7] More recently, the usage of social media such as Facebook and Twitter has mushroomed.[8] Some have suggested that the communications revolution has led to the "death of distance", i.e., the reduction of the role of distance in communications (Cairncross 2001). [9]

3. Increase in income. An important aspect of modernity is the increase in income 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; at the same time there have been major improvements in other indicators of well being such as life expectancy and education.[10] The proportion of global population with income less than $1.90 per day (2011 PPP) has decreased from over 42% in 1981 to less than 11% in 2013,[11] and per-capita world real income has increased by a factor of 10 over the last two centuries (Bolt et al. 2014).[12]

4. Growth of secular and religious opportunities. Modernity has brought many new opportunities both in the secular (e.g., in entertainment and tourism) and the religious (e.g., televised worship events, more affordable travel to pilgrimage sites) domains. In some countries (notably Turkey, Egypt and Iran), authorities in the early to mid-twentieth century

similar individuals, where similarity increasingly reflects educational attainment and decreasingly reflects race.

[7]For example, Internet usage increased from 11% in 1997 to 81% in 2016 in the developed world and from 2% to 47% in the global population (International Telecommunication Union data)

[8]Pew Research Center (2018) finds that 78% of 18- to 24-year-olds in America use Snapchat, and a sizeable majority of these users (71%) visits the platform multiple times per day. Similarly, 71% of this age group now use Instagram and 45% use Twitter.

[9]The role of various media in maintaining relationships over long distances has been studied for example by Utz (2007).

[10]IMF World Economic Outlook 2000.

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

[12]While income has generally increased, trends in income inequality are mixed: within-country measures of inequality dropped sharply in most major economies over most of the 20th century but since have increased, while inequality across countries moved in the opposite directions (Friedman and McNeill 2013, p.216, 250).

imposed secularization, which increased secular opportunities. While the relative growth of secular and religious opportunities is not entirely clear, we believe that on balance modernity has brought a greater growth of secular opportunities than of religious ones.

5. Growing incompatibility between religious and secular activities. In modern times, religious activities are 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 they tend to occur in separate spheres. The variety and scope of new secular opportunities, together with nondecreasing requirements for religious activities, makes the two spheres more 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). As discussed by Iannaccone (1992), religious movements such as Krishnas, Jehovah's Witnesses, Mormons, and others involve religious practices which are socially stigmatizing and hence also difficult to reconcile with the modern world. Forced secularization, imposed by authorities in many parts of the world, also increases incompatibility.[13]

6. Changes in tolerance. Modernity has arguably had an impact on how tolerant people are towards those who are different from them, e.g., in terms of the level of religiosity. Modernity has likely changed people's tolerance of those with dissimilar levels of religiosity, but we are not aware of data that can identify the strength or even the direction of the impact. Public support for civil liberties, such as freedom of religion and expression, has generally increased in the United States over the last few decades. However, the impact varies across demographic groups.[14] Overall, one might expect that the impact of modernity on tolerance varies significantly across and within societies.

Our simulations try to capture these modifications via shifts in particular parameters. In Section 4, we describe the parameters of the simulation model in detail, and in Section 4.6, we connect these parameters with the changes brought by modernity discussed above.

[13] An example 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).

[14] For example, the support for allowing an anti-religionist (somebody who is against all churches and religion) to make a speech rose overall from 66.1% in 1972 to 76.4% in 2012. However, for those with education at college level or higher, the proportion has slightly fallen from 92% in 1972 to 88.9% in 2012 (NORC, 2012).

In Section 5, we then analyse the impact of modifications of values of these parameters on the long-run distribution of religiosity of the agents.

3 Related Literature

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 other scarce resources to allocate to secular activity and how much to participation in the religious club. Each individual benefits from the quality of the religious club, which is determined by the members' overall participation level. By imposing behavioral requirements, religious clubs increase the cost of secular activity, which can be thought of as a tax on such activity. The paper shows that, despite imposing unproductive costs, these behavioral requirements can in fact increase the club members' equilibrium welfare.[15] More recent club models of religion include Berman (2000) and 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 several ways. First, our agents interact via a spatial network, in which each individual agent is affected most by nearest neighbors. Second, in addition to club interactions, our agents also interact directly with their neighbors. Third, to widen the focus from an individual group or club to the national or world level, we modify the payoff function to directly incorporate the impact of a club's idiosyncratic behavioral requirements. 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. Although our agents and interactions are quite different from theirs, Iannaccone and Makowsky (2009) and Makowsky and Rubin (2013) use a methodology similar to ours to examine how different exogenous parameter vectors impact aggregate behavior.

Our paper also adds to the literature on religious extremism and fundamentalism, which

[15]The effectiveness of unproductive costs in increasing participation in clubs and increasing individual welfare is documented empirically by Aimone et al. (2013), who test a simplified club good model in lab experiments. The paper also provides evidence for endogenous group formation, which is not relevant to the current version of our model.

includes club models of religious fundamentalism (Iannaccone 1997, Berman 2000), and models of religious strictness (McBride 2015, Levy and Razin 2012), and connects with the literature on secularization and on simulation models of religion (Shy 2007). Within these strands of literature, our paper is most closely related to studies of the emergence and spread of religious extremism or fundamentalism. We are aware of only five such papers, as follows. Our paper aims to help fill this gap in the literature.

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 decide on their shares of social control (over norms, religion, etc.) through a Nash demand game. Arce and Sandler (2009) consider a similar model and introduce assortativity of pairwise matching in order 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. However, they consider a population which consists of a leader of a sect and his followers, where the leader chooses the required level of observance that is optimal for him. Makowsky (2012), like us, spatially embeds a club model of religion. Unlike us, he uses a cellular automaton, with agents located on a two-dimensional uniform lattice. Instead of a continuous religiosity variable, he assumes a fixed set of religious groups, each requiring a particular level of sacrifice from its members, and labels as "extremist" the groups with the highest levels of required sacrifice. 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). Our paper differs from Makowsky (2012) in that our model has endogenous levels of religiosity, more flexible neighborhoods and a wider variety of interactions. Furthermore, our analysis focuses on how a bimodal distribution of agents' commitment to their religious clubs can emerge in the population.

4 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 $t = 1, ..., T$ by her physical location L_i and her degree of religiosity $r_i(t) \in [0, 1]$. In this paper, we hold

L_i constant over time but simulate adjustments in religiosity $r_i(t)$ due to interactions with other agents.[16] The analysis focuses on the distribution of religiosity in the long run, after the distribution seems to have reached stochastic equilibrium.

We describe the model in detail in the following subsections. In particular, we note that the model includes a number of parameters, which we introduce step by step below.

4.1 Definition of Religious Fundamentalism in the Simulation Model

Our qualitative definition of fundamentalism combines the group trait "extremely high level of religiosity in comparison to the rest of the society" with "a relatively cohesive group in terms of the level of religiosity", which we highlighted in Section 2.1. To operationalize that definition, we use a standard statistical package (the R algorithm expectation maximization, EM) to estimate a mixture of two normal distributions for a simulation's final religiosity levels $r_i(T), \quad i = 1, ..., N$. Let μ_1 and μ_2 denote respectively the upper and lower estimated modes. Then we say that the distribution exhibits *(weak) fundamentalism* ($F = 1$) if

i. $\mu_1 > 0.8$, i.e., the upper mode is at a high level of religiosity, and

ii. $\mu_1 - \mu_2 > 0.2$, i.e., the upper mode of religiosity is noticeably higher than the lower mode.[17]

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, the following condition holds

[16] This is different from Smaldino and Epstein (2015), who study a model with mobile location, whereas in our paper we hold the location L_i constant over time but simulate adjustments in religiosity $r_i(t)$ through interactions with other agents. To clarify, the religiosity in our paper could be viewed as the social position mentioned in Smaldino and Epstein (2015) and the physical location in our paper could be viewed as an exogenous social structure. However, while Smaldino and Epstein (2015) study how self-organization produces social conformity, our interest lies in the interactions among agents.

[17] The value of 0.2 is related to the mean value of tolerance in the population (discussed in Section 4.3), which is also 0.2. These values ensure that what we refer to as a direct interaction (also discussed in Section 4.3) between an agent from the so-defined fundamentalist group of the population and an agent from the rest of the population "on average" will not bring their levels of religiosity closer to each other, but rather further apart.

iii. the standard *dip test* of Hartigan and Hartigan (1985) for bimodality rejects the null (unimodal) hypothesis at p-value less than 0.10.

Condition iii ensures that the two groups are separated, not just by distance between typical members as in ii, but also in terms of cohesion: there is a relatively small overlap of the members' level of religiosity. The critical p-value does not seem very important; p = 0.05 produces qualitatively similar results. See Figure 1 for a schematic illustration.

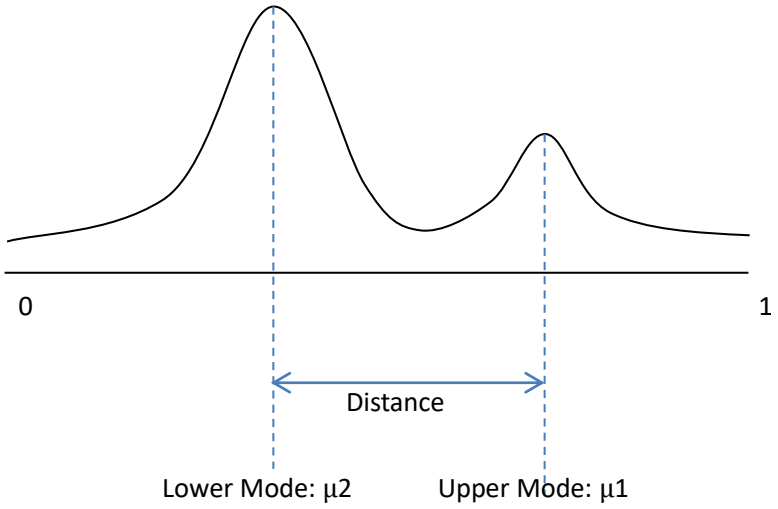

Figure 1: Operational Definition of Fundamentalism. A religiosity distribution exhibits fundamentalism ($F = 1$) if the position μ_1 of the upper mode, and the distance $\mu_1 - \mu_2$ between the upper lower modes are each sufficiently large.

Our definition of (weak) fundamentalism captures religious extremism, both in absolute and relative sense. That is, for a distribution to exhibit (weak) fundamentalism, there must be a substantial group of agents who have an extremely high level of religiosity in absolute terms as well as relative to the rest of the population. A high level of religiosity can be understood here as a high attachment to the set of core beliefs, e.g., in the inerrancy of scripture, and high involvement in the religious community, e.g., through participation in religious and social events, active evangelization, etc. A notable implication of this definition is that a population where all agents are very religious is not classified as fundamentalist. We think that is appropriate because such uniformity seems less likely to provoke political and social discord.

Our definition of strict fundamentalism requires that fundamentalists form a group that is not only extremely religious in absolute and relative sense, but is also cohesive. Thus the presence of agents with extreme religiosity is not enough; they also need to have a relatively similar level of religiosity. Such similarity is often achieved by fundamentalist movements through imposing behavioral requirements in domains such as worship, attire, and diet, and through setting sharp boundaries between members and non-members.

4.2 Overview of the 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 small example with $N = 20$ agents.

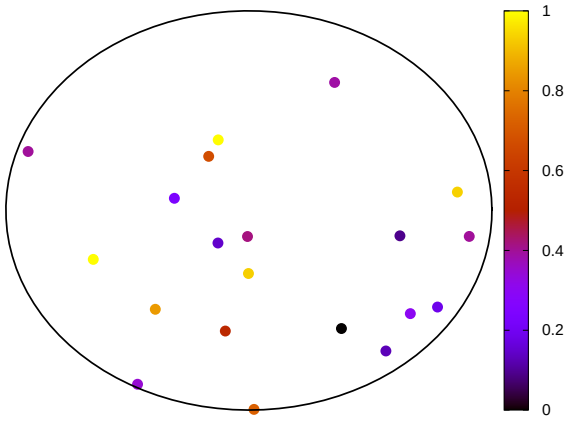

Figure 2: An Example of Simulation Initialization. The surface of the sphere is shown in Mollweide projection, a pseudo-cylindrical view that preserves areas but (especially towards the poles) distorts angles. Religiosities $r_i(0)$ are color-coded from yellow (near 1.0) to dark violet (near 0.0).

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 is then updated incrementally via a small 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.

Since religiosity is bounded above by 1 and below by 0, the increments cannot be additive. We therefore use multiplicative increments that ensure that religiosity does not drop below 0 or exceed 1, implemented using the following variant on the log function. Each iteration deterministically transforms the chosen agent A's religiosity $r \in [0, 1]$ to a value $R \in [-\infty, \infty]$ via the 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 function $\mathcal{L}(x) = \frac{\exp(x)}{1+\exp(x)} = (1 + \exp(-x))^{-1}$. Thus, when $C + D + n = 0$, we have $r' = \mathcal{L}(R(r)) = r$, and religiosity is unchanged. The transformations are order-preserving and smooth, and updates $C + D + n$ are almost always small, so in each iteration the increments $r' - r$ are also almost always small. The next two subsections explain the update terms C and D in more detail.

Figure 3 tracks religiosities in a sample simulation of $N = 20$ agents for $T = 1$ million iterations. Note that two distinct groups soon emerge in this 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 ($F = 0$).

4.3 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 baseline values are $N = 100$ and $K = 0.16$. The $N = 100$ choice is simply a normalized population size and the $K = 0.16$ choice implies that a typical agent has about three neighbors.

Link strengths decrease in the distance d between a pair of agents; the strength is proportional to d^{b_d}, where the distance sensitivity parameter $b_d \in [-3, 0]$ has baseline value -1.0, which represents a linear decaying effect. We use the "small world" technique (Watts and Strogatz 1998) of breaking each local link with probability $\beta \in [0, 0.5]$ and replacing it with a link to an agent selected at random irrespective of distance. The idea is that a few

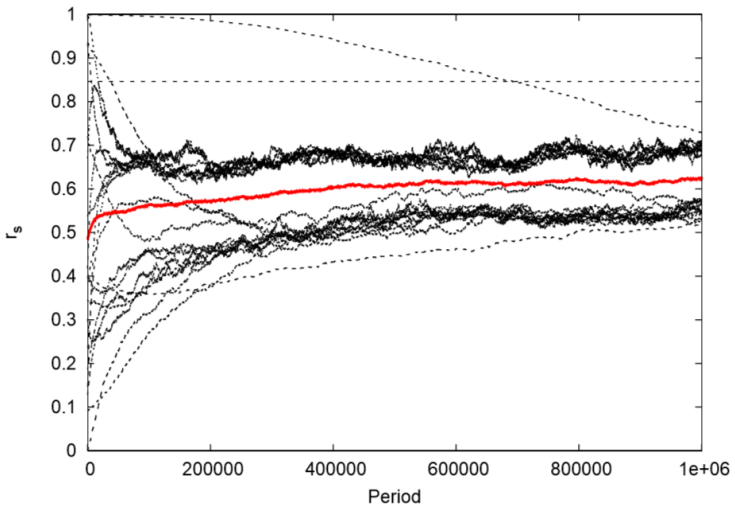

Figure 3: Simulation Example. Number of agents is $N = 20$, with $T = 1,000,000$ iterations; other parameters are at baseline values. Black dotted lines trace religiosities for individual agents, and the red solid line is their overall mean. In this example, bimodality emerges in the distribution of religiosity, with μ_1 and μ_2 equal approximately to 0.67 and 0.55, respectively.

long distance links can greatly shorten the indirect paths connecting distant agents, e.g., two agents on opposite sides of the world might now both be neighbors of some agent with a long distance link, and thus be indirectly connected. To avoid attenuating this small world effect, we introduce a new distance sensitivity parameter $b_{sm} \in [-2, 0]$ that applies to replacement links; the baseline value is $b_{sm} = 0$, i.e., no attenuation. Thus link strength is governed by parameters K, β, b_d and b_{sm}, with natural baseline values.

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

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

Baseline tolerance is $\lambda = 0.20 \pm 0.02$, i.e., each agent's λ is drawn independently from a Normal distribution (truncated to [0, 1]) with mean 0.20 and standard deviation 0.02. 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 direct 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 direct interaction effect D brings them closer together.

The idea behind the tolerance parameter λ goes back at least to the psychology literature on biased assimilation. There is substantial evidence on people being attracted to (or tolerant of) similar others and repulsed by (or intolerant of) dissimilar others in various domains, including religion. For example, 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 mechanisms of attraction to similarity and repulsion from dissimilarity have been studied for example by Skvoretz (2013), who explores these two mechanisms as drivers of intra- and intergroup relations using data on interethnic marriages in the UK and the US; on US dating and cohabitation relations by religion and education; and on educational diversity in marriages in 22 European countries. Other studies exploring similarity attraction and dissimilarity repulsion such as Berscheid and Walster (1969), Byrne (1971), and Rosenbaum (1986) show that in general people are most attracted to others who share similar important attitudes, such as attitudes concerning home and family rather than those who share less important attitudes.[18]

The parameter $q \in [0, 1]$ in equation (1) governs the importance of direct interactions relative to the peer group effects presented in the next subsection. To the extent that social capital inheres in peer groups, the expression $1 - q$ can be interpreted as a measure of the level of social capital. We discuss this matter further in Section 4.6.

4.4 Peer Group Interaction Parameters

The other term C in our simulation model is based on the club goods model of Iannaccone (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 the budget constraint

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

[18] See also the International Encyclopedia of the Social Sciences (2018).

Thus, utility is a constant elasticity of substitution (CES) function of secular activity S and religious subutility,[19] 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 parameter b controls the substitution elasticity $\eta = \frac{1}{1-b}$ between S and religious subutility. Note that $\eta > 0$ for $b \in (0, 1)$ and $\eta \to \infty$ as $b \to 1^-$. 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 incompatible.[20] In the simulations reported below, c in equation (4) is not another exogenous parameter; instead, it is a variable tuned so that club goods payoff is maximal when $r = Q$. The idea is to streamline Iannaccone's model by absorbing into the payoff function the impact of individual groups' behavioral requirements. See online Appendix C.2 for details.

Our parametrization holds constant the price level p_s of ordinary ("secular") goods and varies nominal income I and the relative price $p = p_r/p_s$ of religious goods. We assume that each agent's income is drawn from a lognormal distribution with mean log income μ_I and standard deviation of log income σ_I. [21]

Baseline values are $b = 0.8$ for fairly close substitutability; $a = 0.3$ for moderately more than proportional weight on own contribution to the peer group when it includes at least 3 other members; $P = p_s = 1$ to normalize prices; $p = p_r = 0.55$ as a neutral price index for religious goods; and $\mu_I = 1$ and $\sigma_I = 0.1$ to normalize real income with a realistic degree of inequality.[22]

[19] 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.

[20] Incompatibility means that mixes of secular and religious goods are less desirable. Suppose, for example, that one agent currently consumes a very secular bundle X and another agent is equally happy with a bundle Y with large religious subutility. To the extent that $b > 1$, these agents would be less happy consuming a 50:50 mix of X and Y. 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.

[21] Lognormal income distributions are a standard simplification, and recent evidence confirms that they are good empirical approximations except at the extreme upper tail (Clementi and Gallegati 2005).

[22] Normalizing median log income to 1.0, we obtained the estimate $\sigma_I = 0.0924$ by fitting the lognormal distribution to raw 2017 US income percentile data. Hence our baseline choice $\sigma_I = 0.1$ is realistic.

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 is governed by payoff function ϕ in an incremental manner parallel to the direct (pairwise) interaction update D. The more a change in r increases (or decreases) ϕ, the greater the increase (or decrease) in r coming from C. More precisely, the adjustment term C for adaptation to the peer group is proportional to the payoff gradient,

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

The constant of proportionality is 4 times the relative weight, $1 - q$, on peer group (as opposed to direct) interactions. The factor 4.0 neutralizes the way the R function scales at midrange (i.e., it compensates for $\frac{dR}{dr}(0.5) = 0.25$), but by the same token it implies that the coefficient q in the D term balances the coefficient $4(1-q)$ in the C term when $q = 0.8$. Therefore 0.8 is our baseline value of q.

To summarize, the update term C defined by equation (4) 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 (given their peer group) religious activity, and also taking into account relative costs and available resources. This peer group adjustment is of importance comparable to the direct adjustment D.

For convenience, we collect the parameters of the model in the table below.[23]

[23]Online Appendix A offers a more detailed version of the table, including the baseline parameter values and references to the empirical evidence.

Background simulation parameters	
N	number of agents on the sphere
T	number of iterations of the simulation
σ	noise amplitude in update term in each iteration
Network parameters	
K	size of each agent's neighborhood
β	probability of an agent's neighborhood link being deleted and rewired with a random agent on the sphere
b_d	sensitivity to distance in neighborhood links: higher absolute value implies lower weight on more distant agents
b_{sm}	sensitivity to distance in rewired ("small world") links
Direct vs peer groups interactions parameter	
q	weight of direct update term relative to peer group term
Direct interaction parameters	
λ	agents' tolerance of others' dissimilarity
Peer group interaction parameters	
a	weight attached by each agent to own religiosity (relative to the average religiosity of connected agents)
b	substitutability between religious and secular goods (imperfect substitutes, perfect substitutes, and incompatible respectively for $b < 1, = 1, > 1$)
p_r	price of religious goods
p_s	price of secular goods
μ_I	median log income
σ_I	standard deviation of log income

4.5 Incentives, Optimization and Equilibrium

In what sense do agents in our model respond to incentives? The club goods elements of our model provide the same sort of incentives as in other models in the Iannaccone (1992) tradition. The direct interaction elements create the incentive to have religiosity more like

close neighbors who are not too different, but to contrast even more sharply with sufficiently dissimilar neighbors. The interplay of both sorts of incentives determines whether or not fundamentalism emerges.

As in most dynamic agent-based models, agents in our model respond incrementally to incentives. They do not fully optimize immediately, but rather move religiosity up or down at a rate determined by the net impact of incentives that iteration. Eventually, as behavior settles down after sufficiently many iterations, some sort of equilibrium is achieved.

How many is 'sufficiently many', and what sort of equilibrium? In preliminary work, we increased the number of iterations until it seemed that the religiosity distribution had typically settled down after about $T = 2{,}000{,}000$ iterations, and then doubled that number to $T = 4{,}000{,}000$ iterations for the main results presented below. A more formal name for a settled distribution is 'stochastic equilibrium.' The stochastic element, embodied in a small positive value of the parameter σ, keeps the simulation from getting stuck at unrepresentative local equilibria, and thus provides some robustness. In any iteration of this long-run equilibrium, we may not have all agents precisely optimizing their religiosity given the incentives created by their neighbors, but the agents will closely and robustly approximate such optima.

4.6 Capturing Modernity in the Simulation Model

We constructed the simulation model so as to be able to capture a number of changes brought by modernity, as discussed in Section 2.2. We connect now connect those changes to particular parameters of the simulation model.

1. Decline of Social Capital. Our model captures the decline of social capital in two ways. First, our simulations capture aspects of the decline in social capital via increases in the parameter q. Recall that the direct interaction term has weight q while the peer group interaction term has weight proportional to $1-q$. Thus, one can interpret $1-q$ as a measure of social capital: the lower the level of $1-q$, the lower the weight attached to the utility obtained through the peer group interactions, which in particular includes the utility from the mean religiosity of the peer group, i.e. the level of participation of the other members of the peer group. Therefore, linking it to the definition of social capital mentioned in Section

2.2, the lower the level of $1 - q$, the lower the benefit from the membership in the social organization (such as a network in this case), and thus the lower the level of social capital. Second, an increase in parameter a also captures other aspects of a decline in social capital; an increase in a causes a decrease in the Cobb-Douglas weight $(1 - a)$ an agent places on Q, the mean religiosity of the peer group. Thus, an increase in a represents a decrease in the relative importance of others' contributions to group activities, and—linking it to the definition of social capital—consequently also a lower benefit from the membership in the social organization, and thus a lower level of social capital.

2. Progress in communication and transport technology. The developments in communication and transport undoubtedly increased the interaction intensity between people physically distant from each other. In terms of the model, it seems reasonable to say that modernity increases the parameters K (neighborhood size) and β (probability of long-distance connections). Modernity may also affect the distance sensitivity exponent b_d, but the evidence is mixed. While Cairncross's (2001) "death of distance" claim amounts to saying that $b_d = 0$ in modern times, Bailey et al. (2018) analyze huge Facebook data sets and conclude that friendship link frequency strongly declines in geographic distance.[24] [25]

3. Increase in income. The increase in income and living standards that has been witnessed around the world during the 20th century is simply captured by an increase in the mean income μ_I.

4. Growth of secular and religious opportunities. Modernity has arguably improved both secular and religious opportunities, and so lowered the effective price p_s of secular

[24]The estimated elasticities range from about -2.0 over distances less than 200 miles to about -1.2 for distances larger than 200 miles. The latter is not far from our baseline value $b_d = -1.0$.

[25]Goldenberg and Levy (2009) study empirically the importance of geographic distance in social interactions and also find that "distance is not dead": the volume of electronic communications is inversely proportional to geographic distance. In contrast, Kaltenbrunner and Scellato (2012) analyze online user interactions and geographic proximity in a study of a large Spanish online social service, demonstrating that while geographic distance strongly affects how social links are formed, it plays a negligible role in user interactions. Some recent studies on massive interaction networks have observed a substantial impact of administrative or socio-economic boundaries on human interactions (Ratti et al. 2010; Sobolevsky et al. 2013), indicating that geography still matters for interactions. Leetaru (2018) offers additional evidence that, despite the developments in communication, geographical distance still matters.

goods as well as the price p_r of religious goods.[26] Mass production, trade, and progress in communication and transport surely lower p_s, as do easier access to entertainment, tourism and other services. Of course, advances from Gutenberg's printing press to televangelism and mobile messaging likewise have lowered p_r, as has easier access to worship (e.g., through television or to travel to pilgrimage sites).[27] We suspect that, on balance, p_s has likely decreased more than p_r, implying that modernity has somewhat increased p.

5. Growing incompatibility between religious and secular activities. That religious goods can be substitutable with secular goods provided by the market and secular goods provided by the state has been established empirically (Gruber and Hungerman 2006, Hungerman 2005). The substitutability of religious goods and secular goods is captured by the parameter b in our simulation model. We argue that the modern world may be characterized by *incompatibility* between religious goods and secular goods ($b > 1$). 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.

6. Changes in tolerance. In our simulation model, the tolerance is captured by the parameter λ. Considering the mixed evidence on the changes in tolerance, it seems reasonable to say that the impact of modernity on the mean tolerance parameter λ is ambiguous.

5 Results

We begin by showing the impact of varying key parameters one at a time from baseline values $N = 100,\ T = 4,000,000,\ K = 0.16,\ \beta = 0.05,\ b_d = -1,\ b_{sm} = 0,\ \lambda = 0.2 \pm 0.02,\ q =$

[26]The interpretation of parameters p_s and p_r as shadow prices of secular and religious activities (or "commodities") is outlined in detail by Iannaccone (1992).

[27]For example, the invention of the printing press played an important role in providing easier access to the ideas of the Protestant Reformation and in the ensuing spread of this religious movement in Europe. The connection between the printing press and the spread of the Protestant Reformation is examined empirically in Rubin (2014). Rubin (2017) contrasts Europe and the Middle East, among others, by comparing the expansion of the Protestant Reformation in the former, where the printing press became widely used quickly, with the lack of such a movement in the latter, where the religious establishment prevented the spread of the printing press.

0.8, $a = 0.3$, $b = 0.8$, $p_s = 1$, $p_r = 0.55$, and $\sigma = 0.0005$, with lognormally distributed income I where $\mu_I = 1$ and $\sigma_I = 0.1$. The baseline parameter values were chosen to be reasonable empirically and to illuminate how the model responds. Most of those parameter values have already been explained. Here we note that noise level $\sigma = 0.0005$ seems sufficient to avoid meaningless stagnation while keeping negligible the impact of particular random realizations. We reiterate that $N = 100$ is a convenient convention and that $T = 4,000,000$ seems more than sufficient for behavior to settle down.

In the next subsections, we analyze the impact of the modifications of the parameters corresponding to the aspects of modernity discussed in Section 4.6. The figures in these subsections report summaries of 50 Monte Carlo simulations for each parameter vector. The small dots in the left side panels plot the final (period T) estimated upper and lower modes of agent religiosity in each trial simulation, and the large dots average these across all 50 Monte Carlo trials. The right-side panels plot the fraction of the simulations deemed fundamentalist and strictly fundamentalist.

5.1 Impact of the Decline of Social Capital

Figure 4 analyzes the impact of changing the value of the parameter q, recalling that $1 - q$ is a measure of social capital. Panel B of Figure 4 indicates that, near the neutral baseline value $q = 0.8$, the prevalence of fundamentalism is surprisingly sensitive to this parameter. Increasing the weight q on direct interactions to 0.85 increases the fraction of Monte Carlo trials exhibiting strict fundamentalism, $\hat{F}$, from about 60% to above 90%. On the other side, when q is below 0.75, hardly any trials exhibit strict fundamentalism and even weak fundamentalism is uncommon. Panel A shows how increasing q sharply increases bimodality, as the more religious group moves towards maximal religiosity, and the lower group towards atheism. Evidently, unless tempered by peer group interactions, direct interactions tend to push towards polarization (and hence fundamentalism) in our model with baseline parameters. The upshot is that a modernity-induced decline in social capital, captured as an increase in parameter q, can strongly promote fundamentalism.

As noted in Section 4.6, the other model element that can capture the level of social capital is the Cobb-Douglas weight $1 - a$ on the mean peer group contribution to religious

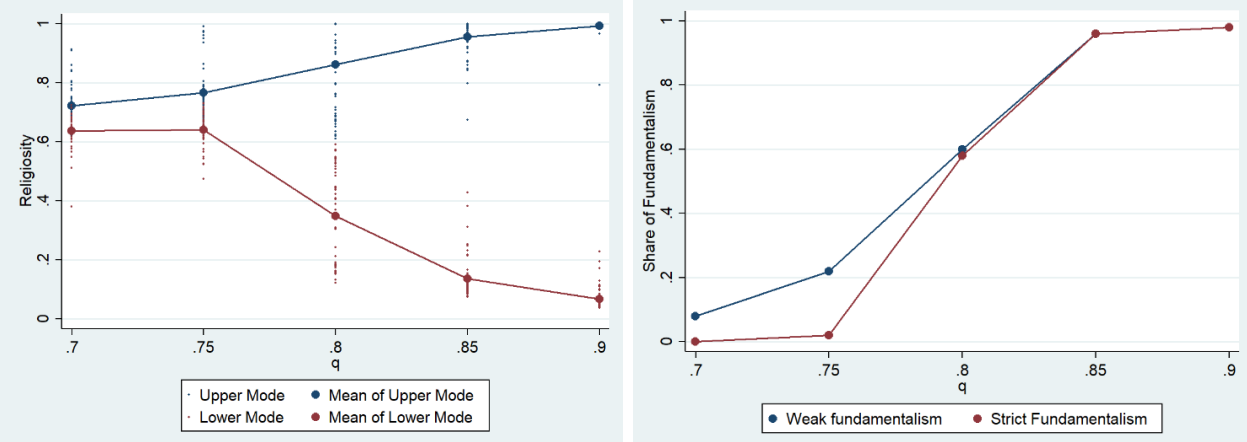

Figure 4: The impact of parameter q (weight of direct (vs peer group) interactions) on the estimated upper and lower modes of religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

subutility. Figure 5 shows its impact. Panel B shows that there is substantially more fundamentalism when a increases much above its baseline value of 0.3 (so that $1-a$ decreases). Evidently, putting lesser weight on the peers' contributions once again enhances polarization, as shown in panel A. On the other hand, putting greater weight on their contributions (e.g., due to an increase in social capital) promotes moderate unimodal distributions of religiosity.

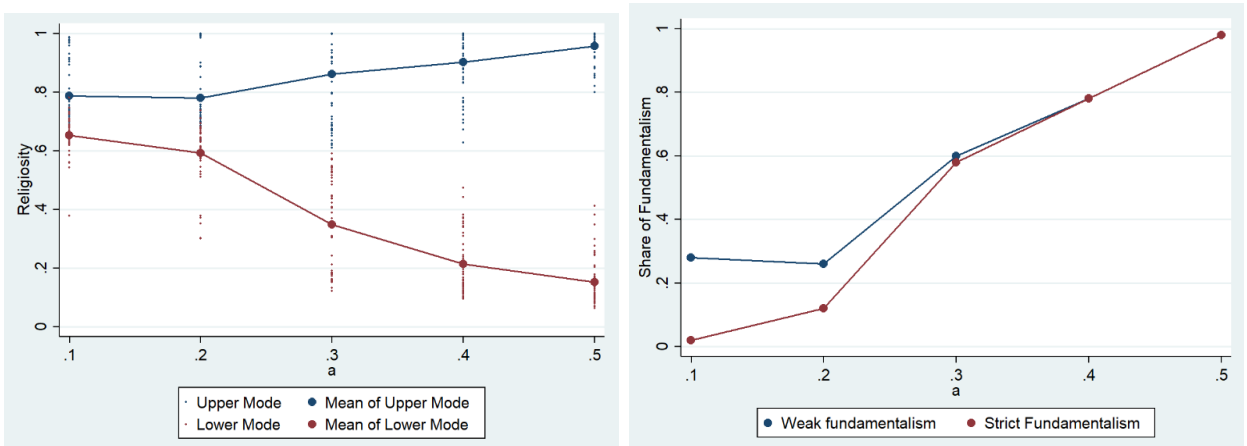

Figure 5: The impact of parameter a (weight of own (vs peer group) religiosity in an agent's utility function) on the estimated upper and lower modes of religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

These comparative static results suggest that a decline in social capital encourages fundamentalism. Both the broader channel via q and the narrower channel via a boost funda-

mentalism in our model when those parameters increase due to a decline in social capital.

5.2 Impact of Communication and Transport Technology

We now consider the impact of parameters that can reflect progress in communication and transport technology. We first consider the typical size of a neighborhood, K. Panel B of Figure 6 shows an increase in strict fundamentalism (from around 30% to nearly 60%) as the neighborhood radius K increases from 0.07 to the baseline value of 0.16, and no clear trend with further increases to 0.25. The upper value implies about $(.25/.16)^2 \approx 2.44$ times the area, i.e., on average more than twice as many neighbors as in baseline, while $K = 0.07$ is so small that many agents have no neighbors and so retain essentially their initial religiosity. Panel A shows that increasing K tends to increase the lower mode (slightly reducing the chance of meeting criterion ii of fundamentalism), but below the baseline value of $K = 0.16$, it also tends to increase the upper mode (increasing the chances of meeting criterion i).

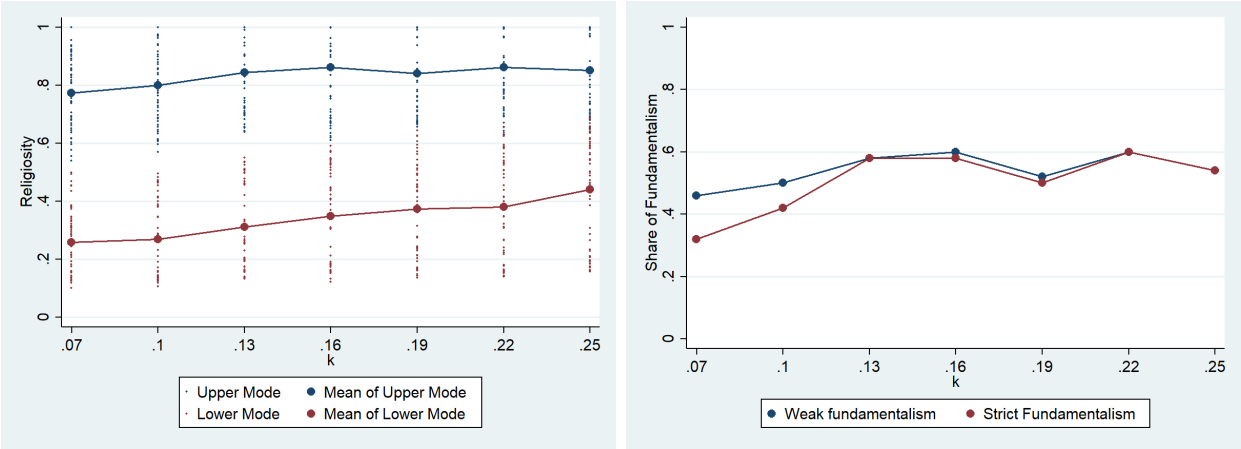

Figure 6: The impact of parameter K (neighborhood radius) on the estimated upper and lower modes of religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

Another parameter controlling the influence of more distant agents is the long-distance rewiring parameter β. Baseline parameter values ensure that the long-distance links have about the same weight as the local links. Panel B of Figure 7 shows that increasing the prevalence of long-distance links from 3 to 7% has very little impact on fundamentalism, and Panel A indicates little effect on the underlying mode distributions.

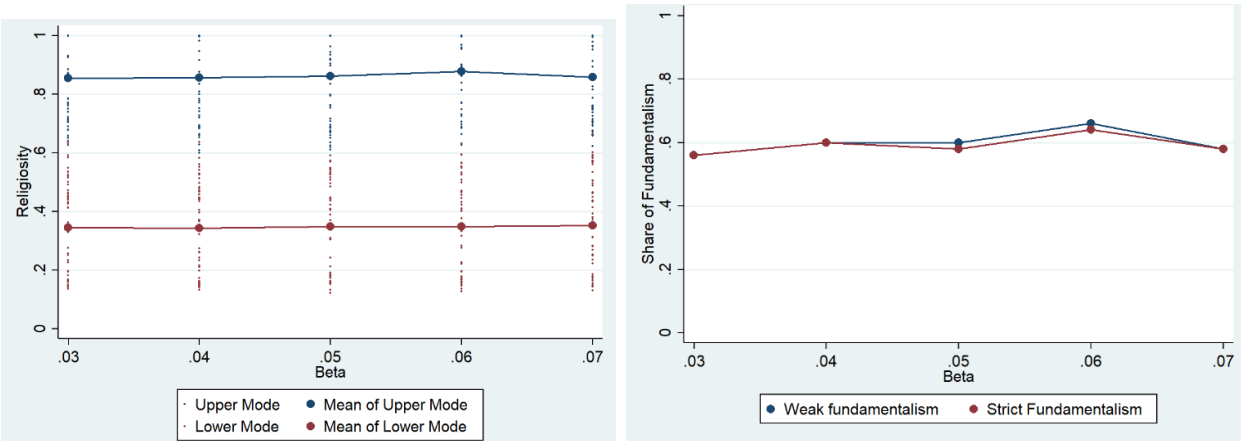

Figure 7: The impact of parameter β (probability of long-distance connections) on the estimated upper and lower modes of religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

Thus, apart from a clear increase in fundamentalism associated with increases in K up to the baseline value of 0.16, these two parameters have surprisingly limited effect.[28]

5.3 Impact of the Increase in Income

We now turn to the analysis of the modifications to the parameter corresponding to income, μ_I. Figure 8 examines income effects directly over the range from 50% below to 50% above baseline median log income μ_I.[29] Panel B shows that fundamentalism indeed increases substantially over this range, from about 35% to about 65%. The proximate reason, seen in Panel A, is that lower income enforces a more moderate distribution of religiosity, while higher median income results in some agents choosing more extreme levels of religiosity (or secularity) and increased bimodality. It seems that people in a very poor society cannot afford ostentation in religious (or secular) display, while polarizing forces have more room to operate at higher income levels. With income above subsistence level, agents can afford a mixed bundle of the two goods that involves a very high consumption of one of the goods,

[28]We also note that the debate whether the distance attenuation parameter b_d has also been affected by modernity has little impact on our conclusions because over the relevant parameter ranges, the updates depend much more sensitively on the number of neighbors, controlled by parameter K, than on parameter b_d.

[29]If baseline $\mu = 1$ corresponds to \$100 per week, then the lower end of the income range in Figure 8 is just \$10/week and the upper end is \$1000/week.

and some agents will focus discretionary spending on religious goods, while others focus on secular goods. Simulations not shown here confirm that, when other parameters are at baseline values, the prevalence of fundamentalism is insensitive to varying log income dispersion σ_I from zero to three times its baseline value of 0.10.

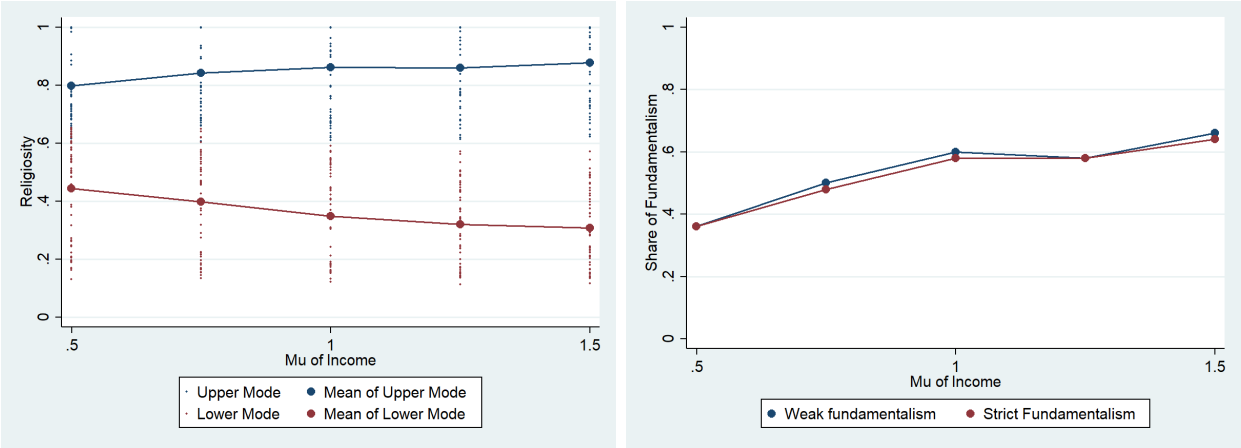

Figure 8: The impact of parameter μ_I (median log income) on the estimated upper and lower modes of religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

5.4 Impact of the Growth of Secular and Religious Opportunities

We next consider parameter p, which reflects the affordability of secular opportunities relative to religious opportunities. Panel B of Figure 9 shows that fundamentalism declines substantially as the relative price $p = p_r/p_s$ of religious goods increases from below to above the baseline value of 0.55. This would seem natural to an economist, but Panel A shows that the story has some nuance. As one would expect, the upper mode decreases in p, but only modestly. By contrast, the lower mode increases in p; evidently the income effect outweighs the substitution effect.

Overall, the effect of modernity on the relative price $p = p_r/p_s$ is ambiguous. We suspect that on balance it has lowered that price. If so, the model offers this as an additional economic explanation for fundamentalism in the modern world, as fundamentalism becomes quite frequent in our simulations as p falls below its baseline value of 0.55 but becomes rare at much higher values of p.

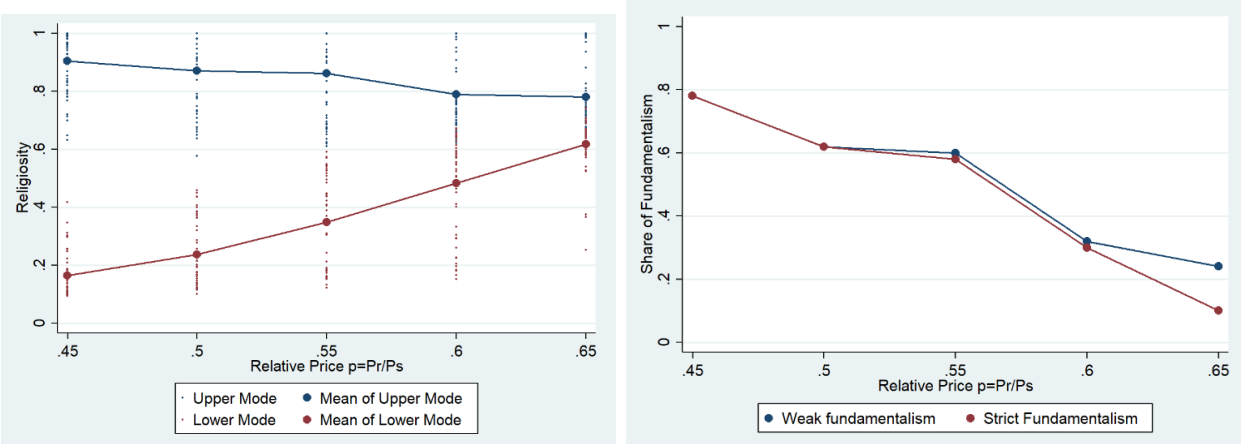

Figure 9: The impact of parameter p (relative price of religious goods) on the estimated upper and lower modes of religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

5.5 Impact of the Growing Incompatibility between Religious and Secular Activities

Figure 10 shows that, when the CES parameter b is less than its baseline value of 0.8 (and other parameters are at baseline settings), there is a tendency towards unimodal distributions of moderate religiosity. The estimated upper and lower modes of religiosity are not far apart and even the former is usually less than 0.8, so strict fundamentalism is rare and even weak fundamentalism is uncommon. However, increasing b to 1.0 and beyond has a strong impact: the population tends towards polarization, and most simulations are deemed fundamentalist. Indeed, for $b = 1.2$, well over 90% of trials exhibit strict fundamentalism. We attribute this to incompatibility which, as discussed in Section 4.4, makes agents prefer to consume a single good rather than a mixed bundle. This tends to push towards corner solutions, with some agents choosing extreme religiosity and others extreme secularity, as confirmed in Panel A.

Thus, our simulations show that incompatibility between religious and secular activities sharply increases the frequency of fundamentalism, because agents then tend to choose a very high (or very low) level of religiosity rather than an intermediate level.

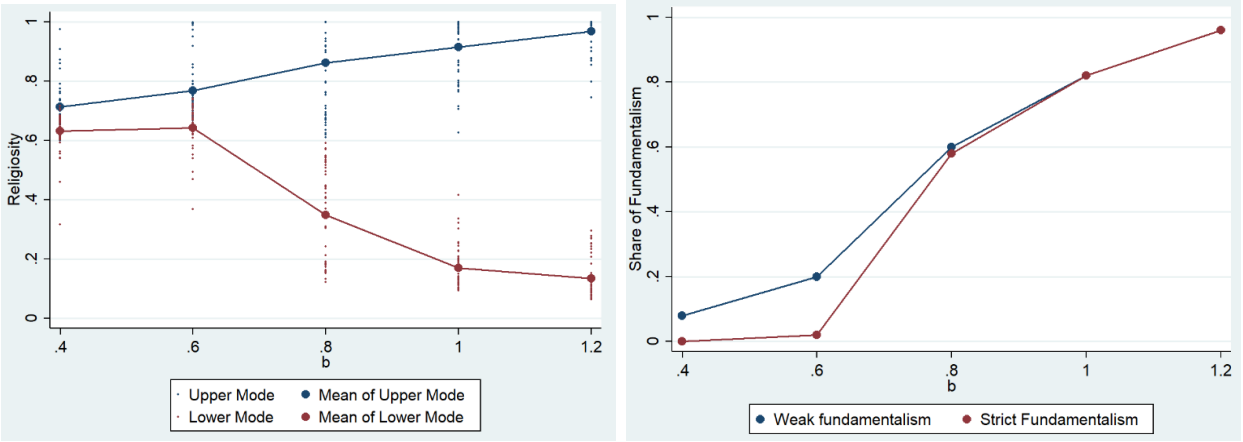

Figure 10: The impact of parameter b (substitutability of secular for religious goods) on the estimated upper and lower modes of religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

5.6 Impact of the Changes in Tolerance

Finally, we examine the tolerance parameter λ. Recall that direct interactions tend to push neighbors' religiosity towards each other when λ is large, and indeed Panel A of Figure 11 suggests that distributions become more moderate (and unimodal) as the average value of λ increases. Below the baseline level 0.20 we see rather polarized distributions and more than 60% of trials exhibit strict fundamentalism. At higher values of lambda, the upper and lower modes move towards each other, so criteria i and ii are less likely to be satisfied and strict fundamentalism appears in less than 20% of trials. Simulations varying the dispersion of λ from zero to two times its baseline value of 2% (with other parameters at baseline values) show very little impact. We conclude that the average tolerance level is what matters in our simulations, and fundamentalism is less likely to appear when agents are more tolerant of others' differing levels of religiosity.

In our model, it seems reasonable to say that the impact of modernity on the mean tolerance parameter λ is ambiguous. The variability may well have increased, but this has little impact on the model's predictions. Wherever the net effect of modernity is a decrease in mean tolerance, we have yet another explanation for the emergence of fundamentalism.

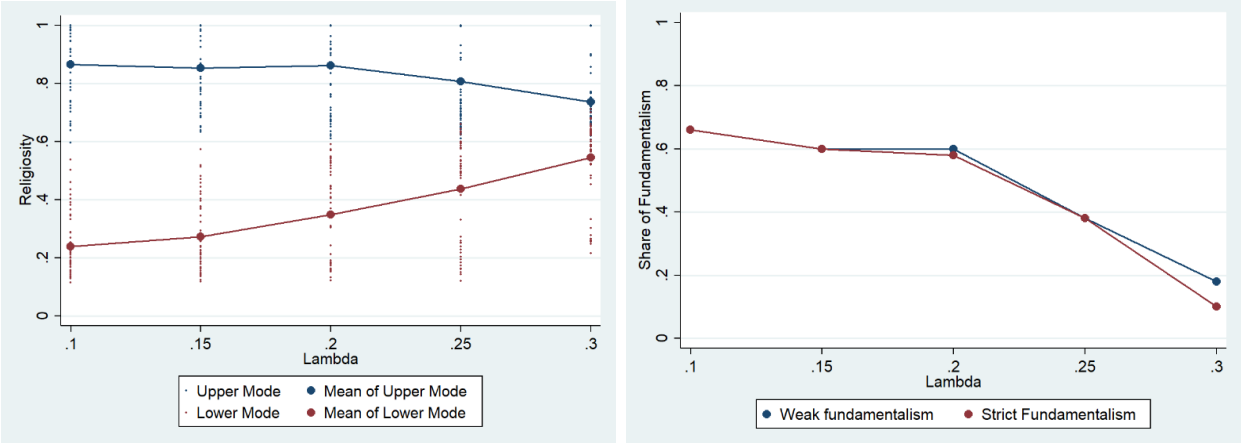

Figure 11: The impact of parameter λ (tolerance) on the estimated upper and lower modes of religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

6 Conclusion

Why has fundamentalism become so prevalent in the modern world? Our approach to this question can be summarized briefly. First, we identify the key characteristics of fundamentalism and the changes associated with modernity. We suggest that fundamentalism is present when there is a coherent minority of the population that is highly religious. We compare the prevalence of fundamentalism across simulations of our model as we vary parameters that reflect the changes associated with modernity.

The model highlights the interplay of two different influences on agents' religiosity: pairwise direct interaction with neighbors (D), and peer group effects from participation in group activities ("club goods", C). In our model, the direct interactions tend to polarize (at baseline values of the tolerance parameter) but, to achieve the necessary cohesion for fundamentalism, peer group effects are also required. Conversely, society tends to become less polarized, and fundamentalism less likely to emerge, when direct interaction extends to larger neighborhoods and so peer groups' initial average religiosity is more moderate. In these and other ways, the interplay of C and D is much richer than we imagined when we first constructed the model.

The simulations suggest that several aspects of modernity may play an important role. The modern world is characterized by lower social capital and higher per capita income, and

the corresponding parameter changes greatly boost fundamentalism in our simulation model. Modernity has made secular and religious activities less complementary, and perhaps even incompatible, which again boosts fundamentalism. The impact of other aspects of modernity is less clear. The relative price of religious versus secular goods and the level of tolerance are important drivers of fundamentalism in our model, but it is hard to say which way modernity pushes them.

As is often the case with simulation models, some of our results surprised us at first. Increases in mean income boost fundamentalism far more than we expected, although in retrospect the mechanism (involving unbalanced baskets containing both religious and secular goods) makes economic sense. We were also puzzled by two null results. The inequality parameter σ_I has no discernible impact on fundamentalism, perhaps because of offsetting effects. The ambiguous impact of modernity on inequality reduces the urgency of solving that puzzle. The other puzzle is the essentially null impact on fundamentalism of the progress in communication and transport technology, reflected in the role of longer distance connections (in particular via the "small world" parameter β). Perhaps again there are offsetting effects.

Our model can be extended in many ways. The definition of fundamentalism can be tweaked, by changing the thresholds or the method of identifying separate modes. The impact of two or three times as many agents can be assessed. Online Appendix C.3 collects some exercises of this sort; they generally suggest that our results are robust. A bit more ambitiously, one could make the world less isotropic: agent location clusters could capture the impact of oceans and mountains and 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 direct interactions probably would require streamlining the peer interactions, but it might lead to new insights. Another important limitation of the present model is that we consider only a single religion. More complicated simulations might consider the interaction of two or more different 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.

References

Aimone, J.A., Iannaccone, L.R., Makowsky, M.D., and Rubin, J., 2013. Endogenous group formation via unproductive costs. The Review of Economic Studies, 80 (4), 1215-1236.

Almond, G.A., Appleby, R.S., Sivan, E., 2003. Strong religion: The rise of fundamentalisms around the world. University of Chicago Press: Chicago and London.

Arce, D.G., Sandler, T., 2003. An evolutionary game approach to fundamentalism and conflict. Journal of Institutional and Theoretical Economics, 159 (1), 132-154.

Arce, D.G., Sandler, T., 2009. Fitting in: group effects and the evolution of fundamentalism. Journal of Policy Modelling, 31 (5), 739-757.

Bailey, M., Cao, R., Kuchler, T., Stroebel, J. Wong, A., 2018. Social Connectedness: Measurement, Determinants, and Effects. Journal of Economic Perspectives, 32 (3), 259-80.

Berman, E., 2000. Sect, subsidy and sacrifice: an economist's view of ultra-orthodox Jews. Quarterly Journal of Economics, 115 (3), 905-953.

Berscheid, E., Walster, E.H., 1969. Rewards Others Provide: Similarity. In *Interpersonal Attraction*, 69-91. Reading, MA: Addison-Wesley.

Bolt, J., Timmer, M., van Zanden, J.L., 2014. GDP per capita since 1820, in van Zanden J.L. et al. (eds.), How Was Life?: Global Well-being since 1820, OECD Publishing.

Brian, K., 2007. OECD Insights. Human Capital: How What You Know Shapes Your Life. OECD Publishing.

Byrne, D., 1971. The Attraction Paradigm. New York: Academic Press.

Cairncross, F., 2001. The Death of Distance: How the Communications Revolution Is Changing our Lives. Harvard Business School Press.

Chen, D.L., 2010. Club goods and group identity: evidence from Islamic resurgence during the Indonesian financial crisis. Journal of Political Economy, 118 (2), 300-54.

Clementi, F., Gallegati, M., 2005. Pareto's law of income distribution: Evidence for Germany, the United Kingdom, and the United States, EconWPA.

Emerson, M.O., Hartman, D., 2006. The rise of religious fundamentalism. Annual Review of Sociology, 32, 127-144.

Epstein, G.S., Gang, I., 2007. Understanding the development of fundamentalism. Public Choice, 132 (3-4), 257-271.

Friedman, D., McNeill, D., 2013. Morals and Markets: The Dangerous Balance. Palgrave-Macmillan, NYC.

Goldenberg, J., Levy, M., 2009. Distance is not dead: social interaction and geographical distance in the internet era. ACM SIGCAS Computers and Society, 2.

Gruber, J., Hungerman, D.M., 2006. The Church vs. The Mall: What Happens When Religion Faces Increased Secular Competition. Quarterly Journal of Economics, 123 (2), 831–62.

Hartigan, J.A., Hartigan, P.M., 1985. The dip test of unimodality. The Annals of Statistics, 27 (3), 70-84.

Hood, R.W., Hill, C.H., Williamson, W.P., 2005. The psychology of religious fundamentalism. The Guildford Press: New York and London.

Hungerman, D.M., 2005. Are Church and State Substitutes? Evidence from the 1996 Welfare Reform. Journal of Public Economics, 89 (11–12), 2245–67.

Iannaccone, L.R., 1992. Sacrifice and stigma: reducing free-riding in cults, communes and other collectives. Journal of Political Economy, 100, 271-92.

Iannaccone, L.R., 1997. Towards an economic theory of 'fundamentalism.' Journal of Institutional and Theoretical Economics, 153 (1), 100-116.

Iannaccone, L.R., Makowsky, M.D., 2007. Accidental Atheists: An Agent-based Model of Religious Regionalism, Journal for the Scientific Study of Religion, 46 (1), 1–16.

International Encyclopedia of the Social Sciences., 2008. Similarity/Attraction Theory. (source: https://www.encyclopedia.com/social-sciences/applied-and-social-sciences-magazines/similarityattraction-theory)

International Monetary Fund., 2000. World Economic Outlook 2000. Washington, D.C.

Iyer, S., 2016. The New Economics of Religion. Journal of Economic Literature, 54 (2), 395-441.

Iyer, S., Kitson, M., Toh, B., 2005. Social Capital, Economic Growth and Regional Development. Regional Studies, 39 (8), 1015-1040.

Kaltenbrunner, A., Scellato, S., 2012. Far from the Eyes, Close on the Web: Impact of Geographic Distance on Online Social Interactions, Proceedings of the 2012 ACM workshop on Workshop on online social networks, 19-24.

Keddie, N.R., 1998. The new religious politics: where, when, and why do 'fundamentalisms' appear? Comparative Studies in Society and History, 40, 696-723.

Kramer, M., 2003. Coming to terms, fundamentalists or islamists? Middle East Quarterly, Spring, 65-77.

Leetaru, K., 2018. Geography Still Defines Who We Are Connected To In The Social Media Era, Forbes. (source: https://www.forbes.com/sites/kalevleetaru/2018/09/20)

Levy, G., Razin, R., 2012. Religious beliefs, religious participation, and cooperation. American Economic Journal: Microeconomics, 4 (3), 121-151.

Lewis, B., 1998. The political language of Islam. Chicago University Press: Chicago.

Lord, C.G., Ross, L., Lepper, M.R., 1979. Biased assimilation and attitude polarization: The effects of prior theories on subsequently considered evidence. Journal of Personality and Social Psychology, 37 (11), 2098-2109.

Makowsky, M.D., 2011. Religion, clubs, and emergent social divides. Journal of Economic Behavior & Organization, 80 (1), 74-87.

Makowsky, M.D., 2012. Emergent extremism in a multi-agent model of religious clubs. Economic Inquiry, 50, 327-347.

Makowsky, M.D., Rubin, J., 2013. An Agent-Based Model of Centralized Institutions, Social Network Technology, and Revolution. PLoS One, 8 (11).

Marty, M.E., Appleby, R.S. (Eds.)., 1991. Fundamentalism project: fundamentalisms observed, Vol.1. University of Chicago Press: Chicago.

McBride, M., 2015. Why churches need free-riders: Religious capital formation and religious group survival. Journal of Behavioral and Experimental Economics, 58 (C), 77-87.

McPherson, M., Smith-Lovin, L., Brashears, M.E., 2006. Social Isolation in America: Changes in Core Discussion Networks over Two Decades, American Sociological Review, 71(3), 353-375. (source: https://doi.org/10.1177/000312240607100301)

NORC, 2012. Trends in Public Attitudes about Civil Liberties. General Social Survey 2012 Final Report, University of Chicago.

OECD Insights: Human Capital (source: https://www.oecd.org/insights/37966934.pdf)

Patacchini, E., Picard, P.M., Zenou, Y., 2015. Urban Social Structure, Social Capital and Spatial Proximity, CEPR Discussion papers.

Pew Research Center., 2015. Teens, Technology & Friendships, Chapter 1: Meeting, Hanging Out and Staying in Touch: The Role of Digital Technology in Teen Friendships. (source: http://www.pewinternet.org/2015/08/06/chapter-1-meeting-hanging-out-and-staying-in-touch-the-role-of-digital-technology-in-teen-friendships/)

Pew Research Center., 2018. Social Media Use in 2018. (source: http://www.pewinternet.org/2018/03/01/social-media-use-in-2018)

Putnam, R.D., 1995. Bowling alone: America's declining social capital. Journal of Democracy, 6 (1), 65-78.

Putnam, R.D., 2000. Bowling Alone: The Collapse and Revival of American Community. New York: Simon & Schuster.

Ratti, C., Sobolevsky, S., Calabrese, F., Andris, C., Reades, J., Martino, M., Claxton, R., Strogatz, S.H., 2010. Redrawing the Map of Great Britain from a Network of Human Interactions. PLoS One, 5 (12): e14248. (source: https://doi.org/10.1371/journal.pone.0014248)

Robbins, J., 2004. The globalization of Pentecostal and charismatic Christianity. Annual Review of Anthropology, 33, 117-43.

Rosenbaum, M.E., 1986. The Repulsion Hypothesis: On the Nondevelopment of Relationships. Journal of Personality and Social Psychology, 51 (6), 1156-1166.

Rubin, J., 2014. Printing and Protestants: An Empirical Test of the Role of Printing in the

Reformation. Review of Economics and Statistics, 96 (2), 270-286.

Rubin, J., 2017. Rulers, Religion, and Riches: Why the West Got Rich and the Middle East Did Not (Cambridge Studies in Economics, Choice, and Society. Cambridge: Cambridge University Press.

Ruthven, M., 2012. Islam: A Very Short Introduction. Oxford University Press.

Shy, O., 2007. Dynamic models of religious conformity and conversion: Theory and calibrations. European Economic Review, 51 (5), 1127-1153.

Skvoretz, J., 2013. Diversity, Integration, and Social Ties: Attraction versus Repulsion as Drivers of Intra- and Intergroup Relations, American Journal of Sociology, 119 (2), 486-517. (source: https://doi.org/10.1086/674050)

Smaldino, P.E., Epstein, J.M., 2015. Social conformity despite individual preferences for distinctiveness. Royal Society Open Science, 2, 140437.

Sobel, J., 2002. Can We Trust Social Capital, Journal of Economic Literature, 40, 139-154.

Sobolevsky, S., Szell, M., Campari, R., Couronné, T., Smoreda, Z., Ratti, C., 2013. Delineating Geographical Regions with Networks of Human Interactions in an Extensive Set of Countries. PLoS ONE, 8 (12): e81707. (source: https://doi.org/10.1371/journal.pone.0081707)

Sonn, T., 2006. Islamic fundamentalism and political Islam. History Compass, 4 (1), 181-185.

United Nations Development Programme., 2015. Human Development Report 2015: Work for Human Development. New York.

Utz, S., 2007. Media use in long-distance friendships. Information, Communication & Society, 10 (5), 694-713. (source: https://www.tandfonline.com/doi/abs/10.1080/13691180701658046)

Watts, D.J., Strogatz, S.H., 1998. Collective dynamics of small-world networks. Nature, 393, 440-442.

Woodberry, R., Smith, C., 1998. Fundamentalism et al: Conservative Protestants in America. Annual Review of Sociology, 24, 25-56.