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A Simulation Study of How Religious Fundamentalism Takes Root*

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Abstract

Religious fundamentalism is observed across the world. We survey evidence on religious fundamentalism and then investigate its roots by reporting 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 substitutability 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, 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 first survey the evidence on religious fundamentalism across the world and then seek 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

¹ Some simulation models, e.g., those used by the weather service or the Federal Reserve, 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.

dispersed population. The agents interact directly with others and also within peer groups. 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 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 how modernity can affect religiosity. The simulation model therefore includes parameters that can capture aspects of modernity such as the decline of social capital, the progress in communication and transport technology, and the growing incompatibility of religious and secular activities. The simulations show how shifts in such parameters can affect the prevalence of fundamentalism.

Section 2 discusses religious fundamentalism across the world including possible definitions of fundamentalism. Section 3 discusses the changes in society that are associated with modernity, and reviews the related literature. Section 4 introduces the simulation model. Section 5 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 6 summarizes the insights gleaned from the exercise, and suggests future research directions.

Appendices A and B contain supplementary material. Appendix A provides a summary of the parameters of the model. Appendix B describes the simulation code in greater detail and includes additional comparative static results.

2 Religious Fundamentalism Across the World

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) was less clear on providing a clear definition of fundamentalism and objective criteria for categorizing religious movements as fundamentalist or non-fundamentalist. In our reading of this literature, 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, behavioral requirements, militancy, and charismatic leadership (see, e.g., Emerson and Hartman 2006).

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. 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.

First, we consider Protestant fundamentalism in the United States. This movement developed 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 declined somewhat after 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.

Second we consider Islamic fundamentalism. Defining “fundamentalism” in the context of the 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)).

Third, we consider 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 Brahma 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.

Finally, we consider 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 in Latin America and Africa.

In this section we described case studies of four fundamentalist movements across the

world. These experiences allow us to distill certain characteristics of fundamentalism that are appropriate for economic analysis, as discussed below.

2.1 Characteristics of Religious Fundamentalism

We now 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 the preceding discussion of 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. 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.

3. 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.

4. Behavioral requirements. Members of fundamentalist movements are required to follow specific behavioral requirements in various domains, such as worship, attire and diet. 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.

5. 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.

6. 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).

7. Millennialism 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 “millennialism”) and by the coming of a Messiah (hence “messianism”). This is particularly characteristic of Abrahamic religions (Almond et al. 2003).

8. 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).

9. 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.

10. 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.

For our present purposes in terms of economic analysis, we can distill the more complex

aspects of fundamentalism down to two key characteristics. 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. 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, and a sharp boundary between members and non-members. We operationalize this verbal definition in Section 4 below.

3 What is Modernity and How Can We Incorporate It in Simulations?

We 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, e.g., industrialization, urbanization, and secularization of education and leisure. For example, Protestant fundamentalism in the United States 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. 1995). Sunni fundamentalism in Egypt grew in the 1970s as a response to the secularization efforts of Gamal Abdel Nasser, whereas Shi'ite fundamentalism in Iran was largely triggered by rapid secularization under the reign of Mohammad Reza Shah Pahlavi (Marty and Appleby 1991).

The aim of this paper is to study how changes brought by modernity may have led to the emergence of fundamentalism. We now list several changes associated with the transition to modernity that our simulations seek to capture; see Section 5.2 for further discussion.

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 organizations and met with family and friends less often than in earlier decades.

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 in wealth. Most of the world saw an unprecedented growth in per capita wealth and improving living standards in the 20th century and early 21st century.

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. 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.

6. Impact on 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.

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

In doing so, 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.² More recent club models of

² The effectiveness of unproductive costs in increasing participation in clubs and increasing individual

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 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. (Arce and Sandler 2003, Arce and Sandler 2009, Epstein and Gang 2007, Makowsky 2011, Makowsky 2012). 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 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 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.

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), 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. 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.

Our paper differs from Makowsky (2012) in several respects. Our model examines fundamentalism (not synonymous with extremism) and has endogenous levels of religiosity, more flexible neighborhoods and a much wider variety of interactions. Makowsky (2011) omits the spatial aspects but otherwise has a setup similar to Makowsky (2012). Our own analysis focuses instead 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 $i = 1, \dots, N$ is described at any time $t = 1, \dots, T$ 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. The analysis focuses on the distribution of religiosity in the long run, after the distribution seems to have reached stochastic equilibrium.

Our verbal definition of fundamentalism combines 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.” To operationalize that definition, we use a standard statistical package (the R

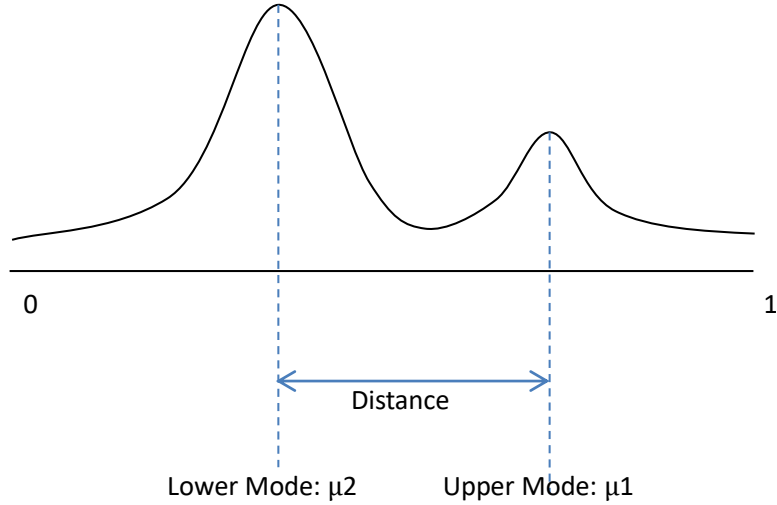


Figure 1: Operational Definition of Fundamentalism. A religiosity distribution exhibits fundamentalism ($F = 1$) if the position μ_1 of the upper mode, and the distance $\mu_1 - \mu_2$ between the upper lower modes are each sufficiently large.

algorithm expectation maximization, EM) to estimate a mixture of two normal distributions for a simulation's final religiosity levels $r_i(T)$, $i = 1, \dots, N$. 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.

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

- 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.

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.

4.1 Overview of 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.

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

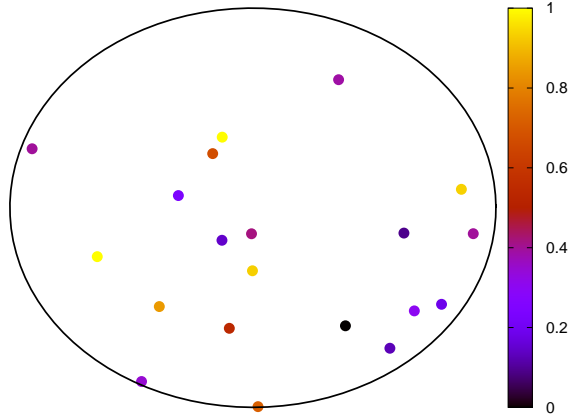


Figure 2: An Example of Simulation Initialization. The surface of the sphere is shown in Mollweide projection, a pseudo-cylindrical view that preserves areas but (especially towards the poles) distorts angles. Religiosities $r_i(0)$ are color-coded from yellow (near 1.0) to dark violet (near 0.0).

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 use essentially multiplicative increments tailored to respect the upper and lower bounds, 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 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 ($F = 0$).

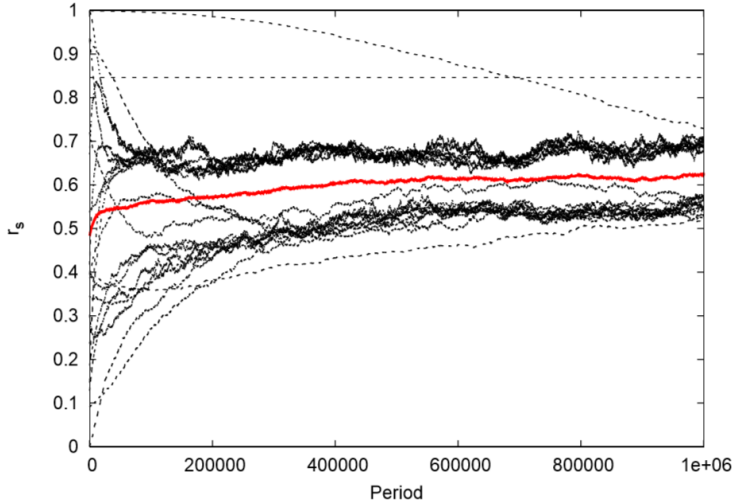


Figure 3: Simulation Example. Number of agents is $N = 20$, with $T = 1,000,000$ iterations; other parameters are at default values. Black dotted lines trace religiosities for individual agents, and the red solid line is their overall mean.

4.2 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.

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 default value -1.0 . 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 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 fairly closely 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} .

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

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

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. 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. As discussed in Section 5.2 below, subsequent literature has confirmed similarity-attraction/dissimilarity-repulsion empirically and justified it theoretically.

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

4.3 Club Goods 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

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

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 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 $\eta \rightarrow \infty$ as $b \rightarrow 1^-$. 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 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 Iannacone’s model by absorbing into the payoff function the impact of individual groups’ behavioral requirements. See Appendix B.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 . Baseline values are $b = 0.8$, $a = 0.3$, $P = p_s = 1$, $p = p_r = 0.55$, $\mu_I = 1$, and $\sigma_I = 0.1$.

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

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

The peer group update C then is the scaled payoff gradient

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

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

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.

activity and (given their peer group) religious activity, and also taking into account relative costs and available resources. The factor 4.0 neutralizes the way the R function scales at midrange (i.e., it compensates for $\frac{dR}{dr}(0.5) = 0.25$), and the factor $1 - q$ reflects the importance of peer group update C relative to direct interpersonal influence D .

4.4 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.

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, and then doubled that number to $T = 4$ million 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.

5 Results

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

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 $\sigma_I = 0.1$. Most of these parameter values 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 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 Comparative Statics

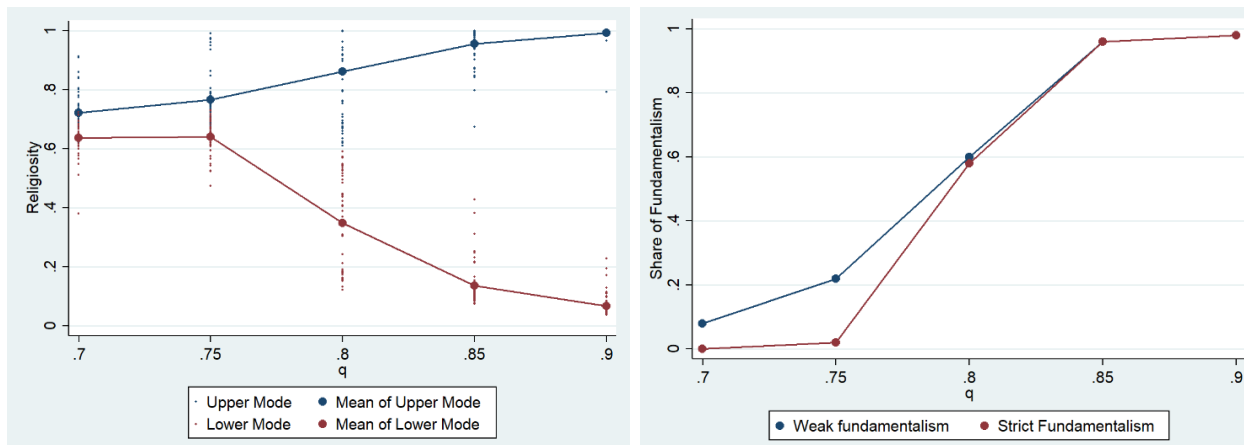


Figure 4: The impact of parameter q (weight of direct (vs peer group) interactions) on the estimated upper and lower modes of religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

Panel B of Figure 4 indicates that, near default values of parameters, the prevalence of fundamentalism is surprisingly sensitive to the balance between direct interaction and club goods. Increasing the weight q on direct interactions to 0.85 (from default value 0.80) 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 club goods effects, direct interactions tend to push towards polarization (and hence fundamentalism) in our model with baseline parameters.

To better understand the push towards fundamentalism, consider the impact of varying the typical size of a neighborhood. Panel B of Figure 5 shows an increase in strict fundamentalism (from around 30% to nearly 60%) as the neighborhood radius K increases from 0.07 to the default 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).

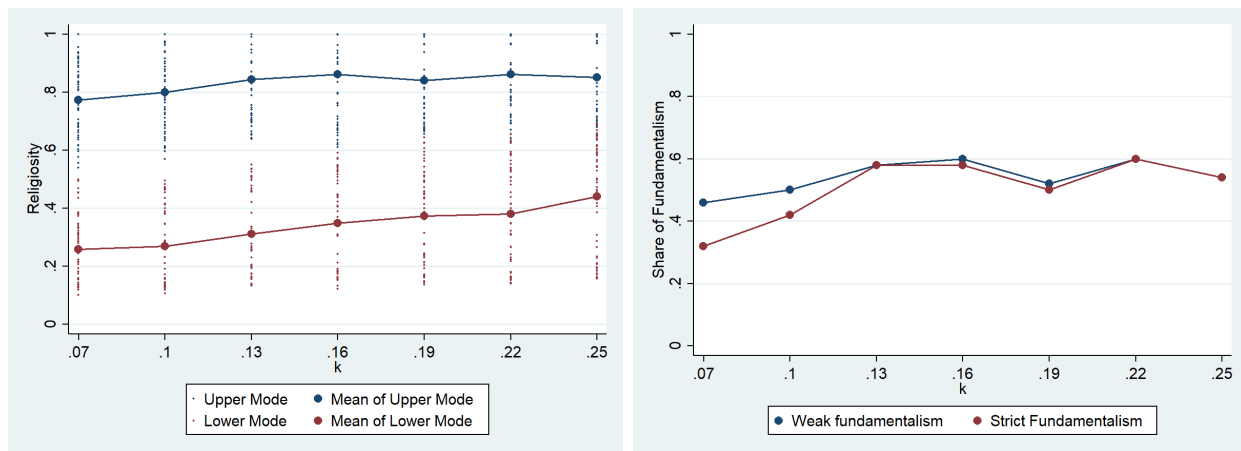


Figure 5: The impact of parameter K (neighborhood radius) on the estimated upper and lower modes of religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

Another parameter controlling the influence of more distant agents is the long-distance rewiring parameter β . Default parameter values ensure that the long-distance links have about the same weight as the local links. Panel B of Figure 6 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. 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.

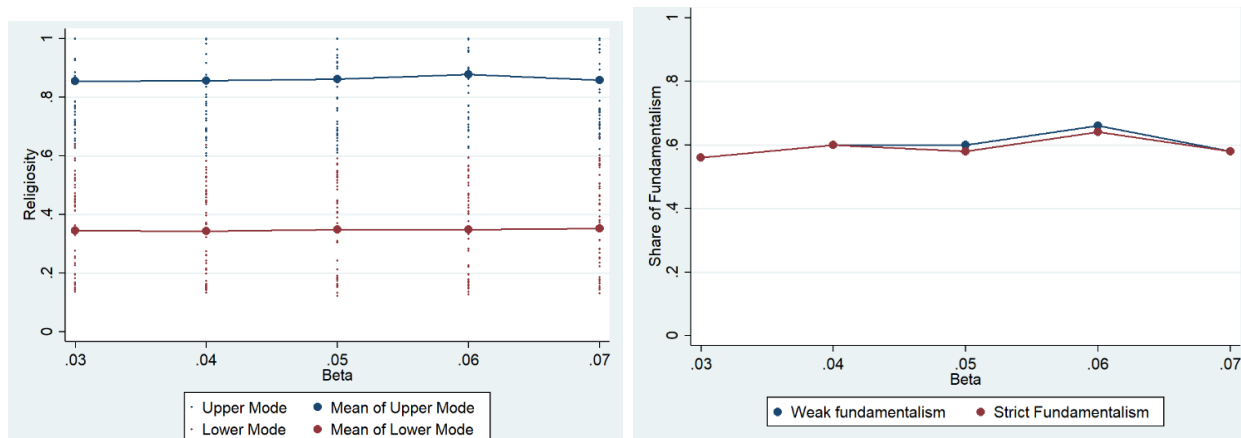


Figure 6: The impact of parameter β (probability of long-distance connections) on the estimated upper and lower modes of religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

Let us now 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 7 suggests that distributions become more moderate (and unimodal) as the average value of λ increases. Below the default level 0.20 we see rather polarized distributions and more than 60% of trials exhibit strict fundamentalism. At higher values of λ , 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.

Turning to parameters controlling the peer group effects, we see from Panel B of Figure 8 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.

Figure 9 examines income effects directly over the range from 50% below to 50% above baseline median log income μ_I . Panel B shows that fundamentalism indeed increases sub-

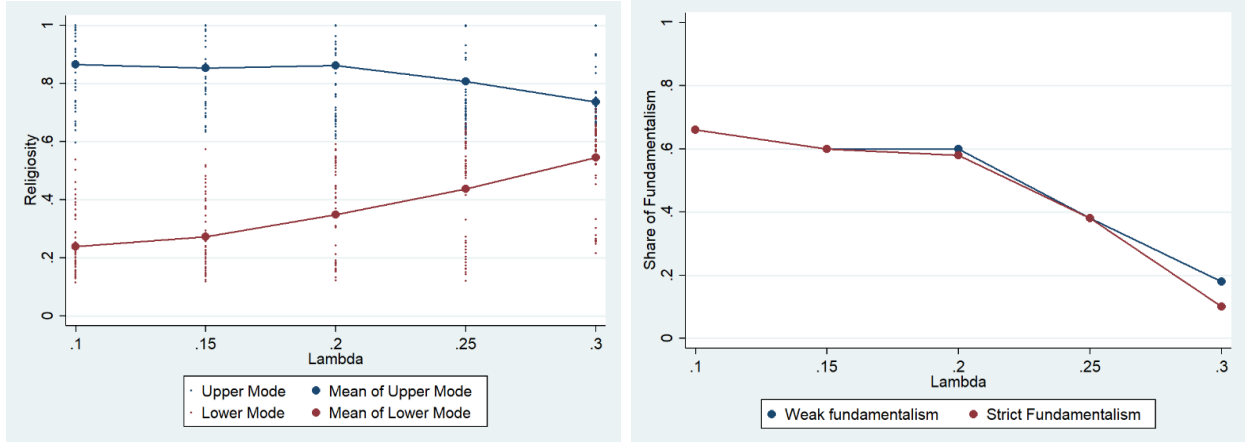


Figure 7: The impact of parameter λ (tolerance) on the estimated upper and lower modes of religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

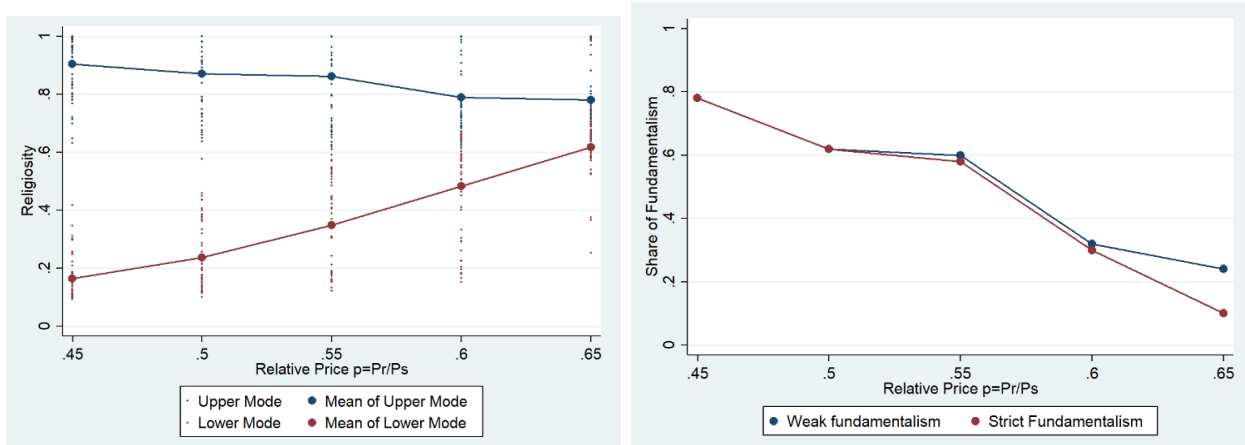


Figure 8: The impact of parameter p (relative price of religious goods) on the estimated upper and lower modes of religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

stantially 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 income results in some agents choosing more extreme levels of religiosity (or secularity) and increased bimodality. It seems that poor people cannot afford ostentation in religious (or secular) display, while polarizing forces have more room to operate at higher income levels. That is, agents with high income can afford a mixed bundle of the two goods that involves a very high consumption of one of the goods. Simulations not shown here confirm that, when other parameters are at baseline values, the prevalence of fundamentalism is insensitive to varying income dispersion σ_I from zero to three times its baseline value of

0.10.

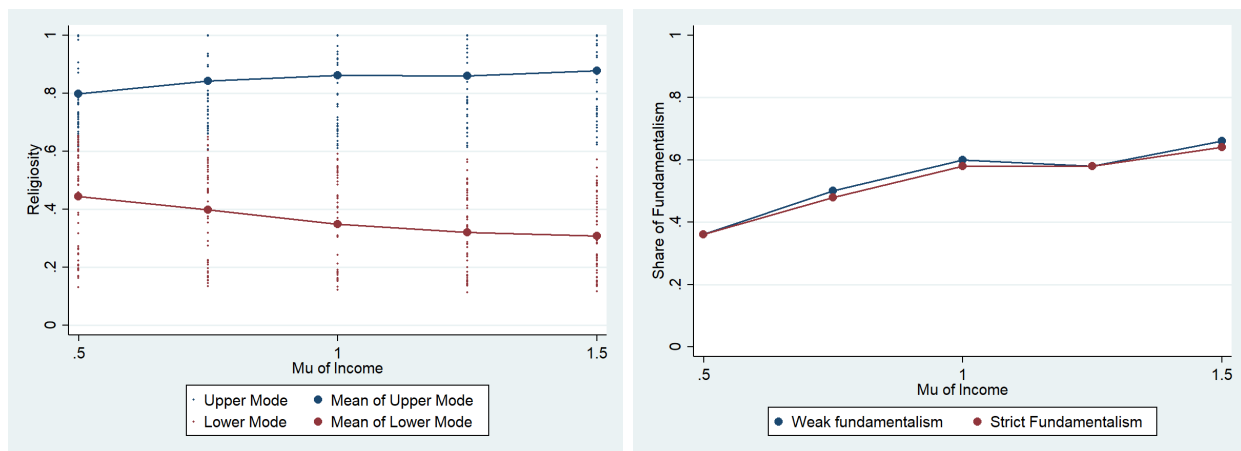


Figure 9: The impact of parameter μ_I (median log income) on the estimated upper and lower modes of religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

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 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 anti-substitutability which, as discussed in Section 4.3, 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.

Finally, Figure 11 shows the impact of the Cobb-Douglas parameter a in religious substitutability. Higher a puts less weight on the peer group’s average religiosity and more on own religiosity. Panel B shows that there is substantially 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, as shown in panel A. On the other hand, putting greater weight on it promotes a unimodal distribution of moderate religiosity. That is, as a decreases, the peer group’s average religiosity plays a bigger role in each agent’s consumption decision and — through the club good interactions in their overlapping neighborhoods — agents tend to

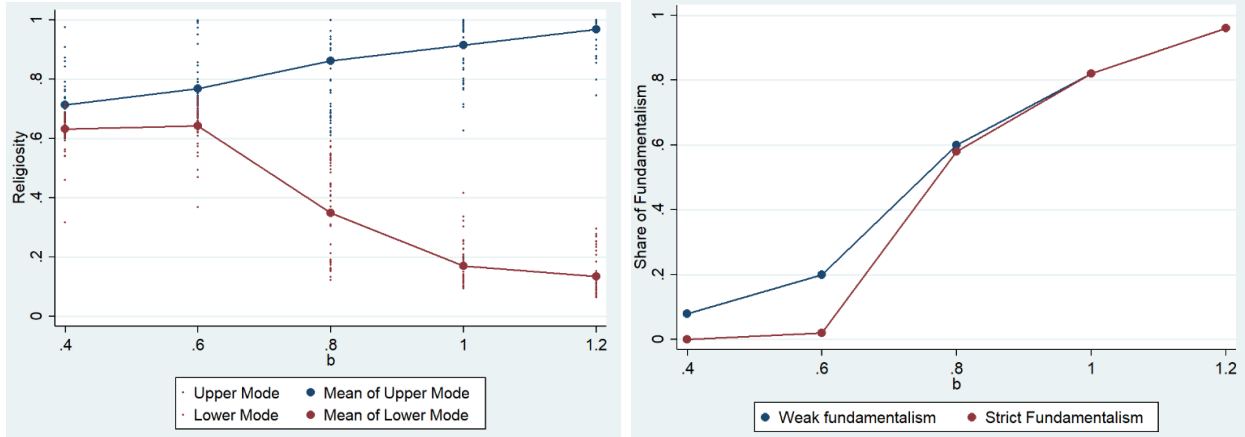


Figure 10: The impact of parameter b (substitutability of secular for religious goods) on the estimated upper and lower modes of religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

choose a similar level of religiosity.

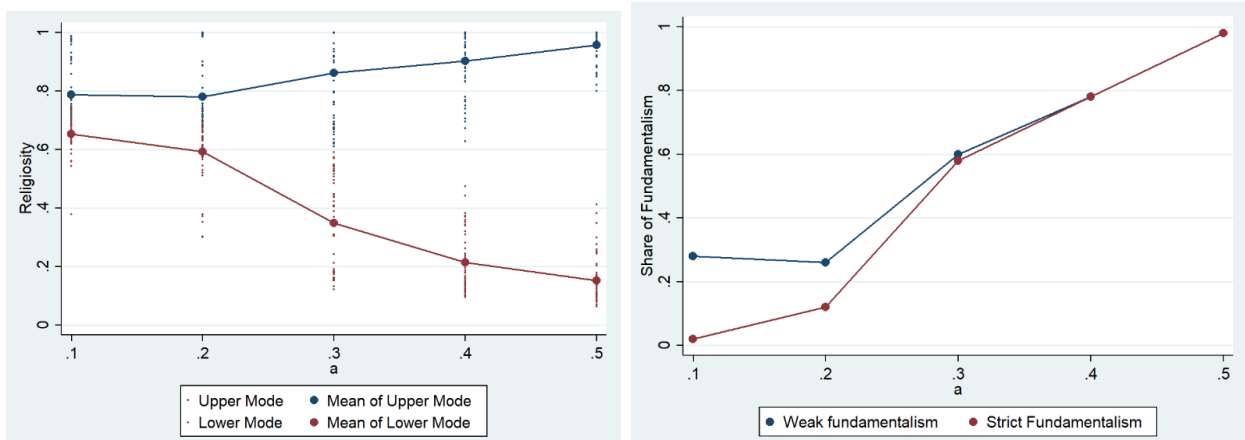


Figure 11: The impact of parameter a (weight of own (vs peer group) religiosity in an agent's utility function) on the estimated upper and lower modes of religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

5.2 Capturing Modernity

The baseline parameter values were chosen to be reasonable empirically and to illuminate how the model responds. Here we tie them more closely to the empirical literature and to

the transition to modernity.⁵

Decline of social capital. It has been argued, most famously by Putnam (1995, 2000), that there has been a significant decline in the social capital over the last few decades. Drawing on more than half a million interviews in the US conducted over 25 years, Putnam 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 generally confirms Putnam’s findings, but adds nuance. For example, McPherson, Smith-Lovin and Brashears (2006) find that most peer groups consist of rather similar individuals, where similarity increasingly reflects educational attainment and decreasingly reflects race.

Our simulations capture such decline in social capital via increases in parameters a (weight of own (vs peer group) religiosity in an agent’s utility function) and q (weight of direct interactions relative to peer group interactions). The comparative static results show that increases in either of these parameters above baseline values greatly encourage fundamentalism.

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. 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). More recently, the usage of social media such as Facebook and Twitter has mushroomed. 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. Some have suggested that the

⁵ The parameters not discussed here (N , T , σ) are only simulation conventions.

communications revolution has led to the “death of distance”, i.e., the reduction of the role of distance in communications (Cairncross 2001). The role of various media in maintaining relationships over long distances has been studied for example by Utz (2007).

These 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). Our model suggests that, up to a point, increases in K can indeed increase the prevalence of fundamentalism. Surprisingly, the model shows no impact for β , an issue we will revisit in the concluding discussion. 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.^{6 7} However, the debate 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 to the distance attenuation parameter b_d .

Increase in wealth. An important aspect of modernity is the increase in 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; at the same time there have been major improvements in other indicators of well being such as life expectancy and education.⁸ The proportion of

⁶ 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 of -1.0.

⁷ 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.

⁸ IMF World Economic Outlook 2000.

global population with income less than \$1.90 per day (2011 PPP) has decreased from over 42% in 1981 to less than 11% in 2013,⁹ and per-capita world real income has increased by a factor of 10 over the last two centuries (Bolt et al. 2014). 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).

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). 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. It turns out that changes in σ_I have minimal impact on the prevalence of fundamentalism in our model. By contrast, our model suggests that the unequivocal large increase in median income in the modern world played a major role in the rise of fundamentalism.

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 goods as well as the price p_r of religious goods.¹⁰ Mass production, trade, and progress in communication and transport surely lower p_s , as do easier access to entertainment, tourism and other services. 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).¹¹

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

⁹ World Bank data: <http://data.worldbank.org/topic/poverty>.

¹⁰ 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).

¹¹ 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.

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 .

Growing incompatibility of 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, Jehovahs 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. 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).

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). 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 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. Our simulations show that anti-substitutability 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 one.

Tolerance. 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.¹² 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. For example, the support for allowing an anti-religionist (somebody who is against all churches and religion) to make a speech rose from 66.1% in 1972 to 76.4% in 2012. However, the impact varies across demographic groups. 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). Overall, one might expect that the impact of modernity on tolerance varies significantly across and within societies.

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.

6 Discussion

Why has fundamentalism become so prevalent in the modern world? Our approach to this question can be summarized briefly. First, we curated the evidence on fundamentalist movements across the world and identified their key characteristics. Then, we suggest 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 funda-

¹² As mentioned earlier, the literature on this topic dates back at least to Lord et al. (1979). 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. See also the International Encyclopedia of the Social Sciences (2018).

mentalism across simulations of our model as we vary parameters defining direct interactions and peer group interactions.

The simulations suggest that several aspects of modernity may play an important role. The modern world is characterized by lower social capital, higher per capita income and more contact with more distant agents, and the corresponding parameter changes greatly boost fundamentalism in our simulation model. Modernity has made secular and religious activities less complementary, and perhaps even “anti-substitutable,” which again boosts fundamentalism. The impact of other aspects of modernity is less clear. Tolerance and the relative price of religious versus secular goods are important drivers of fundamentalism in our model, but it is hard to say which way modernity pushes them.

The model highlights the interplay of two different influences on agents’ religiosity: pairwise direct interaction with neighbors (D), and peer 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 coherence for fundamentalism, it seems that peer 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.

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 very long distance links, via the “small world” parameter β . Perhaps again there are offsetting effects, or perhaps the effects appear only when the number of agents is far larger.

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. Appendix B.2 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 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.

Appendix A: Summary of Parameters of the Model

	Description of the parameter	Baseline value (and tested range)	References to empirical evidence
<i>Background simulation parameters</i>			
N	number of agents on the sphere	100 (50, 250)	
T	number of iterations of the simulation	4,000,000	
σ	noise amplitude in update term in each iteration	0.0005	
<i>Network parameters</i>			
K	size of each agent's neighborhood	0.16 (0.07, 0.25)	Bailey et al. (2018), Cairncross (2001), Goldenberg and Levy (2009), Kaltenbrunner and Scellato (2012), Leetaru (2018), Pew Research Center (2018), Ratti et al. (2010), Sobolevsky et al. (2013), Utz (2007)
β	probability of an agent's neighborhood link being deleted and rewired with a random agent on the sphere	0.05 (0.03, 0.07)	
b_d	sensitivity to distance in neighborhood links: higher absolute value implies lower weight on more distant agents	-1 (-2, 0)	
b_{sm}	sensitivity to distance in rewired ("small world") links	0	
<i>Direct vs peer groups interactions parameter</i>			
q	weight of direct update term relative to peer group term	0.8 (0.7, 0.9)	Putnam (1995), Putnam (2000), McPherson et al. (2006)

	Description of the parameter	Baseline value and tested range	References to empirical evidence
<i>Direct interaction parameters</i>			
λ	agents' tolerance of others' dissimilarity \pm dispersion thereof	0.2(0.1, 0.3) \pm 0.02(0, 0.04)	Berscheid and Walster (1969), Byrne (1971), Lord et al. (1979), NORC (2012), Rosenbaum(1986), Skvoretz (2013)
<i>Peer group interaction parameters</i>			
a	weight attached by each agent to own religiosity (relative to the average religiosity of connected agents)	0.3 (0.1, 0.5)	Putnam (1995), Putnam (2000), McPherson et al. (2006)
b	substitutability between religious and secular goods (imperfect, perfect, and anti-substitutes respectively for $b < 1, = 1, > 1$)	0.8 (0.4, 1.2)	Gruber and Hungerman (2006), Hungerman (2005), Iannaccone (1992), Makowsky (2011), Makowsky (2012), Marty and Appleby (1991), Ruthven (2012)
p_r	price of religious good	0.55 (0.45, 0.65)	Iannaccone (1992)
p_s	price of secular good	1	Iannaccone (1992)
μ_I ; σ_I	median log income; income inequality	1(0.5, 1.5); 0.1 (0, 0.3)	Bolt et al. (2014), Clementi and Gallegati (2005), Friedman and McNeill (2013), IMF World Economic Outlook (2000)

Appendix B.1: 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 direct interactions versus club); λ (parameter characterizing direct interaction); a , b , p_r , p_s (parameters characterizing 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 initialize 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 I, λ, a, b, p_r and p_s , for each agent. That feature was used only for I and λ in 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.

- **Initialization:** on starting the code performs various initialization operations
 - Read parameters from the command line.
 - Read parameters describing the model from the model parameter file and initialize the corresponding variables in the model.
 - The natural log of income assigned to a given node is drawn randomly and independently from a normal distribution with assigned parameters (μ_I, σ_I) . The tolerance parameter assigned to a given node likewise is drawn from a normal distribution with parameters $(\mu_\lambda, \sigma_\lambda)$ and truncated above at 1.0 and below at 0.0.
 - 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 initialize 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 initialize.

- **Iteration:** after initialization 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 4.2 and 4.3. 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 whether the final state of the network meets the criteria for Fundamentalism as defined at the start of Section 4.

Appendix B.2: Constructing c

The variable c in equation (2) is constructed to align club goods utility maximization with Q , the current mean religiosity in the neighborhood. With $c \equiv 1$ as in Iannacone (1992), club goods utility is maximized at some $r < Q$, reflecting the natural tendency to free ride on others' religiosity. Left unchecked, that tendency would eventually drive r to 0 in each group. Iannacone's point is that successful groups cope by raising the cost of secular goods to their

members (not to the general public) via “stigma and sacrifice,” and he finds circumstances under which such devices can stabilize religiosity at a high level within a cohesive group. Our focus is different. In order to analyze how prices and incomes at the national or world level (and other global parameters) affect the overall distribution of religiosity, we abstract from specific internal stabilization devices and use c to enable club good utility to be stabilized at a positive level that emerges endogenously and varies across groups. To do so, we seek, for any given current value $Q \in (0, 1)$, to maximize clubs good utility at $r = Q$. Writing the first order condition for equation (2), imposing $r = Q$, and solving for c we obtain

$$c = \frac{p_r}{ap_s} \left[\frac{I - p_r Q}{p_s Q} \right]^{b-1}. \quad (5)$$

This expression for c was used in all simulations described in this paper. Note that (with the exception of low a) the value of c is not especially sensitive to parameters within the ranges we consider.

Appendix B.3: Supplementary Simulations

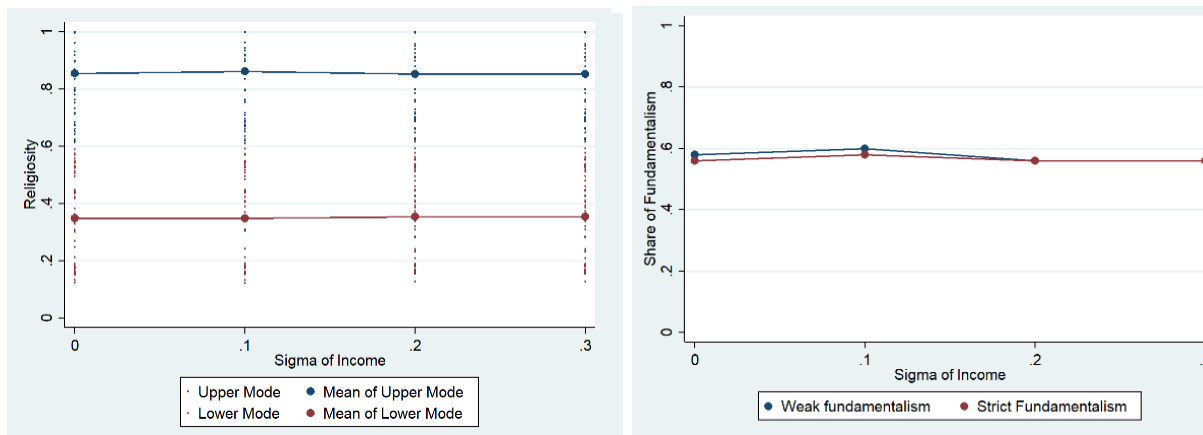


Figure 12: The impact of income inequality parameter σ_I on estimated upper and lower modes of religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

The text asserts that the income inequality parameter σ_I and the tolerance dispersion parameter σ_λ have little impact. Figures 12 and 13 provide evidence.

Figure 14 shows a modest decline in the average location of both upper and lower modes of religiosity, and a corresponding modest decline (mainly due to more frequent below-

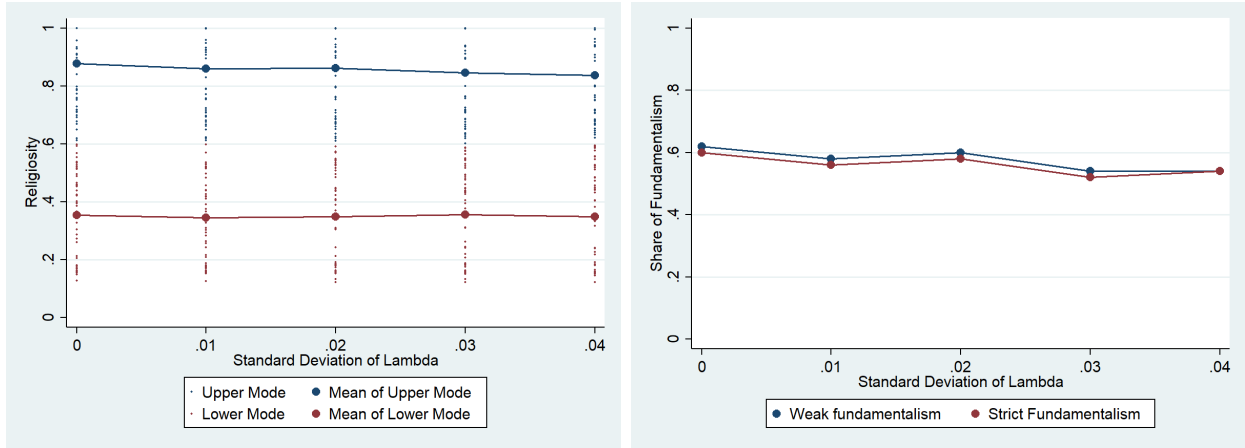


Figure 13: The impact of tolerance dispersion parameter σ_λ on estimated upper and lower modes of religiosity (Panel A) and on the frequency of fundamentalism (Panel B).

threshold upper modes) in fundamentalism as the distance sensitivity parameter b_d increases from below its baseline value of -1.0 to above that value. The neighborhood size K is held fixed in this exercise. The influence of the most distant neighbors is substantially less than that of closest neighbors when $d_b = -2$ but rises to equality as $d_b \rightarrow 0$.

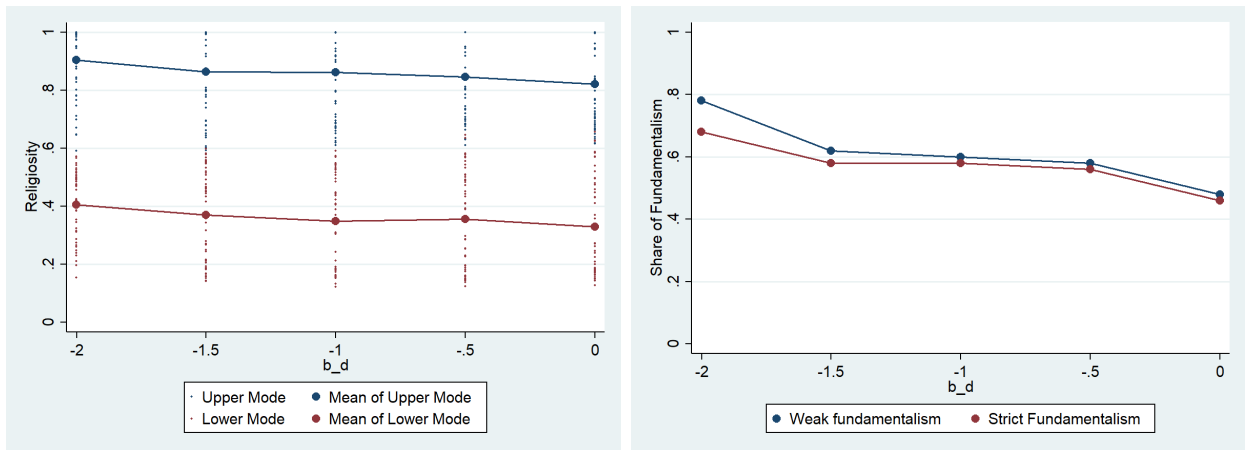


Figure 14: The impact of distance sensitivity parameter b_d on estimated upper and lower modes of religiosity (Panel A) and on the frequency of fundamentalism (Panel B), holding constant the expected number of neighbors.

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 15. We vary K so as to hold constant the expected number of neighbors,¹³ and vary T proportionately with N so as to keep roughly constant the average number of updates of each agent. Panel A of Figure 15 shows very little impact on the average location of upper and lower modes as we vary N from half its baseline value to more than twice that value. There does seem to be some subtle impact on the distributions around that average, so that the rate of strict fundamentalism is slightly below 50% for the extremes $N = 50, 250$ instead of slightly above. Overall, however, the results seem insensitive to N .

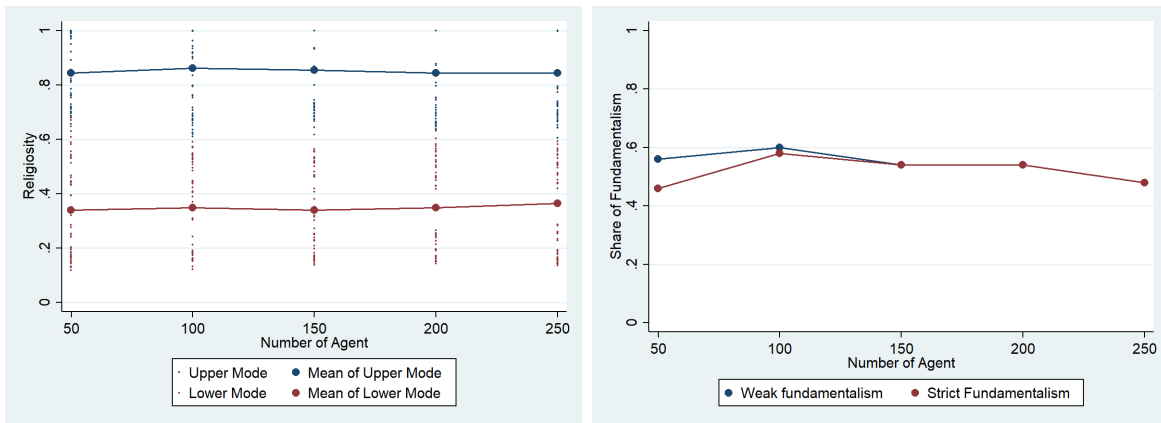


Figure 15: The impact of parameter N (number of agents) on mean religiosity (Panel A) and on the frequency of fundamentalism (Panel B), holding constant the expected number of neighbors.

¹³The 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.

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