The Rise and Fall of Religion: A Model-Based Exploration of Secularisation, Security and Prosociality

Abstract. A number of theories of religion have connected it to psychological and social reactions to environmental threats. For example, Durkheim saw religion as a means to ensure cooperation, Malinowski pointed out the connection between anxiety and ritualisation, and more recently Norris and Inglehart explained secularisation in terms of existential security. One of the difficulties has been tying together the various causal mechanisms that have been proposed; integration of these mechanisms has been unmanageable by traditional means. By using agent-based modelling, however, we have been able to construct and subsequently test a model of the feedback mechanism that could maintain cooperation and high levels of religiosity in traditional societies and the effect upon this state of the introduction of institutions promoting cooperation whose effectiveness was not tied to religion. We have found that such a model is highly plausible and have been able to make specific empirically testable predictions as to the factors that would determine the viability of the equilibrium state and the impact of central institutions upon it.

Keywords: Agent-based model, religiosity, prosocial behavior, existential security.

1 Introduction

For the last one hundred years, the scientific study of religion has very often drawn upon the work of Durkheim and Malinowski who, between them, have identified two aspects of religion that are key to the model developed here. Durkheim [1] characterised religion as primarily serving to create social order, to ensure that members of a community work together for their common good. In the years since, this point has come to be explored by a range of studies[2]–[4] that have often shown that increased religiosity leads to a willingness to behave more altruistically towards the members of one's in-group. Malinowski [5], on the other hand, observed that rituals became more common when people are facing situations that are dangerous and unpredictable. Again, much work has followed this insight, expanding Malinowski's insight to connect anxiety with a range of aspects of religion - including supernatural beliefs - at both individual and societal scales and over time-scales ranging from that of minutes to that of years [6]–[9]. The recently proposed explanation of secularisation in terms of existential security [10] is, in effect, exploring the flip side of Malinowski's insight at the societal scale.

Taken together, the ideas that anxiety drives religiosity and that religiosity promotes prosocial behaviour open the way to conceiving a feedback loop that, outside of fundamental social changes, could lead to an equilibrium state with relatively high levels of social cooperation and religious engagement [11]. The basic causal loop is one where new external threats, that could potentially negatively affect a society, lead to increased levels of anxiety among its members, thereby increasing their engagement with that society's religious traditions. In turn, the strengthening of those traditions leads to their increased ability to promote prosocial behaviour, which makes the society more capable of countering the external threats and thereby maintains the society's stability. Once the threats are eliminated, anxiety can fall leading to decrease in religiosity and cooperation. However, so long as external threats are sufficiently common and significant, religion and prosocial behaviour are maintained over time (Fig 1).

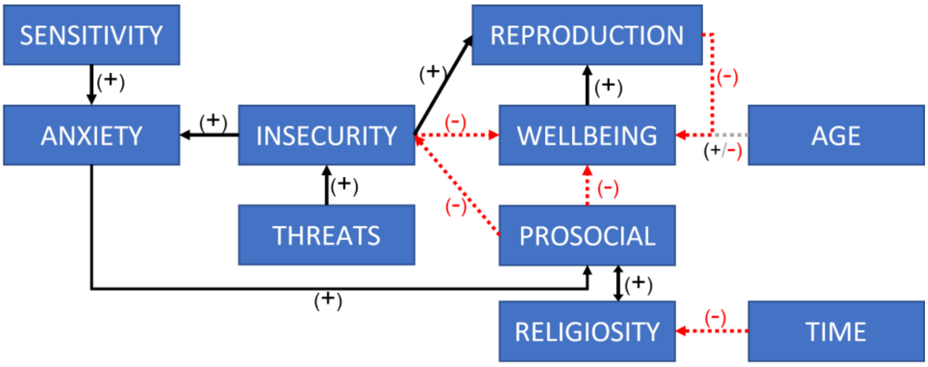

Fig. 1. Model Conceptualization. Red dashed lines represent negative effects and black lines positive ones.

This conception of a religiously-motivated prosocial equilibrium abstracts away from the various other mechanisms that drive altruistic behaviour such as kin selection[12] and reciprocal altruism [13]. This is because those mechanisms have been generally agreed not to be sufficient to explain cooperation in large scale societies - the exact societies that religion is thought to have played a significant role in helping to make possible. Also, there are currently extensive discussions as to the exact psychological/social mechanisms that connect anxiety and religion as well as religion and cooperation, so it has been necessary to treat those aspects of the model conceptualization somewhat abstractly. For example, prosocial behaviour is simply represented as behaviour that is individually costly but beneficial to a number of others and as such it is meant to represent such actions as contributing to religious charities, participating in religious social organisations, and providing mutual assistance to co-religionists on an ad hoc basis. The key element that has been included is that recent research appears to show that adult religiosity is to a great degree determined by exposure to acts of religiously-motivated altruism during socialisation [14].

A previous agent-based model version of this model was tested - and found to lead to plausible results across a wide range of conditions [15]. The aim of the current study is to expand upon the previous results in two ways. Firstly, by exploring the significance of when reproduction takes place in the model. Secondly and more importantly, however, the current study explores the capacity of central institutions - such as those that exist in many modern democracies - that seek to protect members of a society against threats and are supported by universal contributions from all individuals regardless of their religious affiliation. This expansion is particularly significant in the light of existential security theory as it sheds light on the plausibility of that highly influential theory.

2 Methods

The model is written in AnyLogic v.8.7.9. Here we present a brief description of the model. A full ODD+D protocol description and supporting information can be found at the github repository: URL https://github.com/ivanpugagonzalez/Prosociality-ABM-Model-Central-Institutions and in [15].

2.1 Model Overview

The model simulates an artificial society initially inhabited by 1000 human agents who have eight variables: age, gender, marital status, religiosity, wellbeing, insecurity, sensitivity, and anxiety. On initialization, the agents' age distribution is in a pyramid shape (0-100 years), and their religiosity and sensitivity are drawn from a normal distribution with a mean of 0.5 and standard deviation of 0.1. Insecurity is set to 0. Every year, the insecurity of agents increases due to the threats they experience (13 in Table 2). If the insecurity exceeds 1, it will be set to 1. Agents who are 12 years old or older are eligible to perform a prosocial behavior (PB). This behavior occurs when the multiplicative interaction between anxiety and religiosity is above a certain threshold (6 in Table 1). The anxiety of an agent is a combination of their insecurity and sensitivity. Performing a PB increases the religiosity and reduces the insecurity of the performing agent and nearby neighbors (7-10 in Table 1) but is costly and reduces the performing agent's wellbeing (WB) (11 in Table 1). If there are more neighbors than the maximum number of individuals who can be benefited (12 in Table 2), the beneficiaries are selected randomly. In addition, WB increases or decreases according to the agents' current age and insecurity values (14-20 in Table 1). Agents reproduce if they are married, female, and within the reproductive age of 15-49 years old. Agents under 25 years of age reduce their religiosity annually by a set percentage (23 in Table 1). The probability of death is determined by the agents' wellbeing value. The process flow diagram for the model is summarized in Figure 2.

Table 1. Model parameters. ***WB***= wellbeing; ***PB*** = Prosocial behavior; ***Insec*** = insecurity; ***Rep*** = reproduction; ***inc***= increase; ***dec***= decrease; ***rel*** = religiosity; ***CA*** = calibrated parameter, ***SA***= sensitivity analysis; <u>Others</u>: marriage, religiosity decrease, nearby neighbors.

Parameter	Value	Description	Process
1. Rep Cost	CA	% of WB taken from each parent	Reproduction
2. Rep mid threshold	CA	Reproduction probability is 0.5	
3. Rep Curve Shape	CA	Parameters determining the shape of probability of reproduction curve	
4. Importance Insec	0.5		

5. Importance WB	1		
6. PB threshold	SA	Threshold value to trigger PB	Prosocial Behavior
7. PB inc rel self	SA	Increase in agent's and neighbors' religiosity after a PB	
8. PB inc rel neigh	SA		
9. PB dec insec self	SA	Decrease in agent's and neighbors' insecurity after a PB	
10. PB dec insec neigh	SA		
11. PB wellbeing cost	SA	Decrease in agent's WB after a PB	
12. Neigh Benefited	SA	# of nearby neighbors benefited	
13. Threats value	SA	Threat experienced every year	Threats
14. WB Age Threshold	CA	Parameters determining the increase / decrease of WB according to agents' age	Wellbeing-Age
15. WB Intercept C	CA		
16. WB Exp Gain eq	CA		
17. WB Exp Loss eq	CA		
18. WB Insec Threshold	0.1	Parameters determining the increase / decrease of WB according to agents' insecurity	Wellbeing-Insecurity
19. WB Max Inc	CA		
20. WB Max Dec	0.25		
21. Marriage Age Diff	CA	Max age difference between partners	Others
22. Radius Local Area	50	Radius of area of nearby neighbors	
23. Rel Dec Perc	SA	% of religiosity decrease every year	

2.2 Wellbeing processes

WB determines the probability of agents dying according to age and mimics the probability of dying reported in census data. At initialization, wellbeing is determined by a polynomial function of the agents' age. This equation mimics the survival probability of both sexes according to age during 1950's in Norway. This choice was arbitrary, but it doesn't have a major effect on the model's behavior. Both the reference model and the one with prosocial behavior (see below) use the same survival probability curve, and because we compare one against the other the effect of the survival probability curve becomes irrelevant. After initialization, WB of agents increases and decreases every year according to their age. In addition, every year WB is also affected by the agents' insecurity. WB increases if insecurity is below the *WB Insec Threshold* (Parameter 18 in Table 2) or decreases if it is above. For further details on the equations governing the dynamics of agents' WB we refer to our previous study [15].

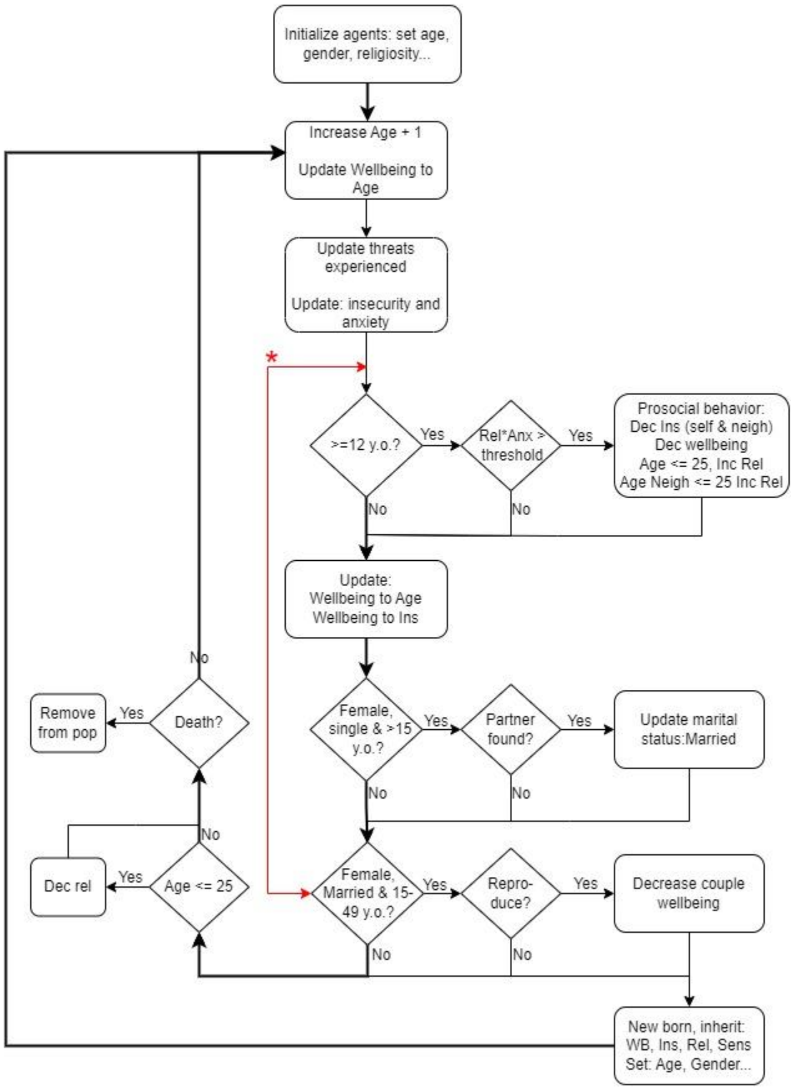

Fig. 2. Model cycle and order of processes. *Depending on the setting reproduction may happen (i) before, (ii) after or (iii) randomly before/after prosocial behavior.

2.3 Marriage and Reproduction

Agents must meet three conditions to get married: (i) being single, (ii) being over 15 years old, and (iii) an age difference not higher than *Marriage Age Diff* between potential partners (Parameter 21 in Table 2). If these conditions are met, agents' marital status are set to married. Once married, female agents in the age of reproduction [15-49] have the chance to reproduce every year. The probability of reproduction depends on the WB and insecurity of the married agents [15]. The loss in WB from both partners is then passed into the offspring, and this value becomes the initial WB value of the offspring. Offspring inherit the religiosity, insecurity, and sensitivity values from one of their parents (this parent is selected at random).

The first difference from our previous study is that here we explore the effect of the scheduling of reproduction: (i) before PB, (ii) after PB, or (iii) at random, i.e., 50-50% chance before or after PB (Fig 2). We explored this effect because insecurity impacts the likelihood of reproduction, i.e., higher levels of insecurity result in a higher likelihood of reproduction. Hence, if reproduction occurs before PB, the parents' insecurity will be high and thus reproduction is more likely; however, if reproduction occurs after PB, the parents' insecurity and wellbeing (WB) levels will be low and thus reproduction is less likely. To account for these variations, the timing of reproduction was scheduled as either before PB, after PB, or at random.

2.4 Reference Model

We created a reference model (RM) to compare the effects of environmental threats and prosocial behavior on the growth rate of society. The purpose of the RM is to establish a baseline for comparison and to determine if the lack of growth in society is due to insufficient environmental threats and prosocial behavior or due to inappropriate parameter values for wellbeing, mortality, marriage, and reproduction. The RM was created by turning off environmental threats and prosocial behavior and calibrating the parameters related to wellbeing, mortality, marriage, and reproduction (CA parameters in Table 1) to values that allow the society to maintain a slightly growing population over time. In the RM, the scheduling of reproduction has no effect since there are no environmental threats or prosocial behavior, and insecurity is always zero. The parameters were calibrated using the optimization engine in AnyLogic, which finds the combination of parameter values that maximizes or minimizes a specific output from an input function. In our case, the input function calculated the residual sum of squares (RSS) between the observed yearly growth rate and the expected if the population size remained constant over time (i.e., 1). The optimization experiments found the combination of parameter values that minimized the output value. We chose the best simulations (from twenty optimization experiments) as RM (see Figure 1 in supporting information and ODD+D protocol for further details on the RMs).

2.5 Simulations

To study the impact of threats on prosocial behavior, religiosity, and society growth, we conducted a sensitivity analysis by varying 9 parameters related to these factors. These parameters are those marked with value SA in Table 1. They are also explicitly listed in Table 2). We used the calibrated parameters of our RM and used latin-hypercube sampling to explore the parameter space 10,000 times (Table 2). The parameters were used to run the model under three different scenarios of reproduction: random, before, and after PB. For each set of parameters, we ran a simulation under each reproduction scenario, each lasting 600 years. We collected the population size and average religiosity of the population every 25 years. Threats and prosocial behavior were introduced in the model after the population reached stability at year 100. A society was considered successful if, at the end of the simulation, its population size was over 2500 individuals. We chose this value as it is greater than the third interquartile range of the RM's population size (SI Fig 1).

Table 2. Parameter space. In bold and italics values that differ from the initial parameter space (1st Analysis).

	1st Analysis		2nd Analysis		3rd Analysis	
	MIN	MAX	MIN	MAX	MIN	MAX
1. PB threshold	0.001	0.500	0.001	***0.100***	0.001	***0.05***
2. PB inc rel self	0.100	0.500	0.100	0.500	0.100	0.500
3. PB inc rel neigh	0.100	0.500	0.100	0.500	0.100	0.500
4. PB dec insec self	0.100	0.500	0.100	0.500	***0.250***	0.500
5. PB dec insec neigh	0.100	0.500	0.100	0.500	***0.250***	0.500
6. PB wellbeing cost	0.001	0.500	0.001	***0.100***	0.001	***0.025***
7. Num Neigh Benefited	0	10	***5***	10	***5***	10
8. Threat value	0.001	0.500	0.001	0.500	0.001	0.500
9. Rel Dec Perc	0.001	0.500	0.001	0.500	0.001	0.500

3 Results

We used the sensitivity assessor tool (available at https://vmasc.shinyapps.io/SensitivityAssessor/), whose use is illustrated in [16]–[18], to examine the conditions that contribute to successful societies in a model. A society was considered successful if its population size was greater than 2500 at year 600. The initial results showed that the majority of societies (80%) became extinct before year 600, and only a very low percentage were successful (<0.04%), regardless of three reproduction conditions (at random, before, after PB). Therefore, we first focused on finding the conditions leading to surviving societies (pop sizes > 0). The sensitivity assessment identified three conditions that when present yielded surviving societies and that when not present, surviving societies were not produced: (1) a PB threshold not greater than 0.1, (2) a PB wellbeing cost not greater than 0.1, and (3) a minimum of 5 neighboring agents. The parameter space was then resampled with these new maximum and minimum values (Table 2, 2nd analysis), and lead to higher percentages of successful societies: 22.95% for random reproduction, 21.98% for reproduction before PB, and 3.83% for reproduction after PB. Further analysis with the Sensitivity Assessor helped identify conditions leading to successful societies. The analysis suggested an even narrower parameter space for PB threshold, PB wellbeing cost, and decrease of insecurity on self and neighbors after PB (Table 2; 3rd Analysis). Running simulations using these values resulted in even higher percentages of successful societies: 44.96% for random reproduction, 74.14% for reproduction before PB, and 24.12% for reproduction after PB.

Our results suggest that the following four conditions are necessary for successful societies. First, the threshold of PB should be low, i.e., PB should be easily triggered in the face of threats. Second, PB should have a low cost for the performing agent. Third, the benefit of PB should be high, i.e., it should decrease insecurity of the performing agent and that of the benefited neighbors. Fourth, PB should benefit at least 5 agents other than the performing agent. Additionally, the logical ordering of reproduction in the model also significantly impacts the growth of societies with the most favorable being reproduction before PB. This is expected. If reproduction occurs before PB, the level of insecurity of the agents is still high, agents are thus more likely to reproduce, and societies grow faster. On the contrary, when reproduction occurs after PB, the level of insecurity of agents has already decreased (due to PB), reproduction is thus less likely and societies grow slower. Furthermore, religiosity appears to be crucial for successful societies - successful societies had an average religiosity value greater than 0.5 (95% of cases) or 0.75 (85% of cases) (see SI Fig 2). Hence, to grow, the majority of societies needed to maintain a high level of religiosity.

We also investigated the impact of stochastic threats and parochial prosociality on the emergence of successful societies. Parochial prosociality refers to the behavior where individuals provide help only to those with similar or higher level of religiosity. When this behavior is activated, agents performing PB benefit neighbors who have a religiosity value higher than their own minus the parochial prosociality parameter value. The lower the value of the parochial prosociality parameter, the higher the required similarity in religiosity between the receiving neighbor and the performing agent to receive the PB benefit. The results of the simulations with stochastic threats were qualitatively the same as those with constant yearly threats (showing how robust the modelled societies were). Parochial prosociality reduced the percentage of growing societies (for detailed results see SI).

3.1 Central Institutions

We explored the effect of Central Institutions (CI) on religiosity and growth in the model. In the model, Central Institutions represent secular institutions that provide security to the population. When CI is activated, all agents are given a reduction in insecurity each year and in exchange, agents above 18 years old pay a cost in the form of a decrease in their wellbeing. The parameter space for implementing CI is presented in Table 3. The values of other parameters remained unchanged from the third analysis (Table 2) except for the maximum values of threat and yearly decrease of religiosity, which were reduced to 0.3 and 0.25 respectively (Table 3). It's worth noting that the maximum cost of CI could be twice as much as the maximum PB cost and the minimum benefit of CI could be 2.5 times lower than the minimum PB cost.

Table 3. Parameter Space with Central Institution. In bold the two parameters related to Central Institutions.

Parameter	MIN	MAX
PB threshold	0.001	0.050

PB inc rel self	0.100	0.500
PB inc rel neigh	0.100	0.500
PB dec insec self	0.250	0.500
PB dec insec neigh	0.250	0.500
PB wellbeing cost	0.001	0.025
Num Neigh Benefited	5	10
Threat value	0.001	0.300
Rel Dec Perc	0.001	0.250
Parochial Prosociality	0.200	1.000
CI WB cost	**0.001**	**0.050**
CI Benefit	**0.100**	**0.500**

As with reproduction, the timing of the CI institution in the model cycle can affect the results. Therefore, simulations were run with the CI institution scheduled both before and after PB and with reproduction at random, before or after PB. This resulted in six combinations (SI Fig 4). Only the results where the CI effect occurs after PB are shown here, as the results are the same regardless of the timing. The effect of threats started at year 100 and that of CI started at year 200, so when CI was turned on, societies had 100 years experiencing threats and religiosity driven PB. The parameter space was sampled 5000 times and used to run the model for 600 years under the six conditions.

Societies were categorized as dying, surviving, or thriving based on a correlation between population size and year. If the correlation was significant and negative ($p<0.1$), the society was classified as dying, if non-significant it was classified as surviving, and if significant and positive ($p<0.1$), it was classified as thriving. Table 4 displays the percentage of populations in each category when the CI effect occurs after PB and the reproduction event occurs after, randomly, or before PB. Table 4 demonstrates that most societies either survive or thrive, particularly when reproduction occurs before PB. The average religiosity of societies at year 600 follows a bimodal distribution in all societal categories and time schedules of reproduction, with most societies having high religiosity (close to 1), but also a significant number having minimal religiosity (0), with few societies in between (see SI Fig 7).

Table 4. Percentage of societal category when CI institution effect occurs after PB and reproduction occurs after, at random, or before PB.

	After	Random	Before
Dying	48.92%	44.24%	7.02%
Surviving	9.46%	6.76%	3.82%
Thriving	41.62%	49.00%	89.16%

As our focus is on societies where CI helps them grow, we next analyzed only thriving societies. Thriving societies were further classified based on a correlation between average religiosity and year. If the correlation was significant ($p<0.1$) and negative, the society was classified as having declining religiosity, if non-significant ($p>0.1$) it was classified as having stable religiosity, and if significant ($p<0.1$) and positive, it was classified as having increasing religiosity. Table 5 shows the proportions of societies with declining, growing, and stable religiosity from year 200 to year 600. Most thriving societies continue to increase their religiosity, but approximately 25% of them have declining religiosity. It is on those thriving societies with declining religiosity (TSDR) that we focus next.

Table 5. Proportions of thriving societies with declining, growing, and stable religiosity according to the different time schedules of reproduction.

		Declining religiosity	Increasing religiosity	Stable religiosity
Reproduction schedule	After	24.10%	70.40%	5.48%
	Random	26.20%	64.10%	9.67%
	Before	15.50%	79.80%	4.76%

We observed that the rate of decline in religiosity varied among TSDR. To better understand this, we divided the TSDR societies into three categories based on the pace of decline in religiosity: slow/medium/fast decline, medium/fast decline, and fast decline (see SI Fig 6). The division was made as follows: the first category included all societies with a negative Pearson correlation between years 200-600, while the second and third categories included societies with an average religiosity of less than 0.5 and 0.125 at year 600, respectively. Using the sensitivity assessor tool, we then investigated the conditions that led to a decline in religiosity in each of these three categories. Table 5 in SI shows the conditions identified by the sensitivity assessor. To identify these conditions, for each parameter we divided its parameter space into specific range values. We then measured the percentage of TSDR that fell within that specific range, i.e., the observed percentage. We also measured the percentage of all thriving societies that fell within that same range, i.e., the expected percentage. The percentages in SI Table 5 are the difference between the observed and expected percentage. A positive value indicates that more TSDR were observed in that range than expected, meaning this parameter range favors the occurrence of TSDR, and vice versa. The yearly increase in threat has the major effect in declining religiosity in thriving societies, as low values (0.001-0.06) favor the occurrence of TSDR, while larger values (>0.06) counter it. This suggests that the CI can handle threats up to a certain threshold, and PB is needed for higher thresholds. Note, however, that this effect could be exacerbated by CI parameters' value space, allowing for larger benefits and lower costs of CI may increase the yearly threat range favoring TSDR. Low values of parochial prosociality (PP) also support the occurrence of TSDR, but to a lesser extent than yearly threat, and this effect decreases as the pace of declining religiosity accelerates (SI Table 5). Low PP values restrict the PB benefit to those with similar religiosity, resulting in fewer neighbors receiving the benefit, causing overall religiosity to decline as religiosity is not reinforced among those without the benefit.

When it comes to the other parameters in SI Table 5, low values of the PB threshold counteract the occurrence of TSDR because, in these cases, PB is easily triggered even at low threat levels, which helps to prevent the decline of religiosity. On the other hand, at high PB threshold values, PB is rarely triggered, and religiosity is not reinforced. This effect is more pronounced in societies with a fast pace of declining religiosity. Additionally, low costs of PB counter the occurrence of TSDR, while high costs favor it. There is no apparent difference among the different paces of declining religiosity. The benefit provided by CI also plays a role, with low benefits countering the occurrence of TSDR and high benefits favoring them. This effect is exacerbated in societies with a fast-declining pace. Interestingly, when the cost of CI is low, the occurrence of TSDR is countered, while high costs favor them. Finally, the yearly decrease in religiosity appears to have an impact on societies with a slow or medium decline pace, with low values countering the occurrence of TSDR, while greater ones favor them.

To evaluate the relative importance of each parameter in relation to others, we analyzed conditions in which we combined the ranges of two parameters (SI Table 6). The lower and upper halves refer to the range values of each parameter. According to SI Table 6, PB threshold and yearly threat are the two most significant parameters affecting the occurrence of TSDR. Even when combined with other parameters, their main effect is reduced but not eliminated. As shown in SI Table 5, low values of PB threshold counteract TSDR, and this is also observed in all combinations of PB threshold values and other parameter values (1-7 to 1-11 in SI Table 6). When PB threshold values are in the lower half of the range, the percentage difference is always negative, indicating that TSDR is countered, and vice versa when PB threshold values are in the upper half, the percentage is positive, favoring the occurrence of TSDR. Therefore, the effect of PB threshold remains regardless of the value of the other parameter. The same holds true for yearly threat, except when combined with PB threshold (1-6 in SI Table 6). In these cases (2-5 in SI Table 6), when yearly threat values are in the lower half, TSDR is favored and vice versa, regardless of the value of the other parameter. Thus, PB threshold and yearly threat seem to play a crucial role in determining the occurrence of TSDR.

Our analyses thus identified at least five parameters that play a crucial role in the emergence of TSDR: PB threshold, threat intensity, yearly religiosity decrease, parochial prosociality and CI benefit.

4 Discussion

The key aim of this model was to examine the conditions under which the existential security provided by secular institutions could lead to secularisation. In this light the two key parameters identified in the model take on added significance. Firstly, it becomes clear that even where secular institutions lead to a pattern of secularisation, this pattern can be potentially overwhelmed by sufficiently large threats that those institutions will be insufficient to deal with - a situation that many western societies may well end up facing in the foreseeable future. Secondly, much depends upon how readily people will engage in religious motivated prosocial behaviour - so we can expect religious traditions that are more successful in motivating such behaviour remaining more relevant in societies with strong secular institutions.

Because of the limited aim of the model, many aspects relevant to the relationship between religiosity and security were either not explored or largely abstracted. As was already noted, while the relationships between the variables have been established, it has not been possible to try and estimate where in the possibility space lie real societies, other than in the most general of ways. This is particularly significant given that in many sets of conditions central institutions were not sufficient to lead to the kind of secularisation that many western societies have witnessed. Also, social structure was treated in very simplistic ways such that it was not possible for small intensely cooperative subgroups to form. Given the viability of the overall model, however, this remains to be done in future work. Also, the counterintuitive effect of increasing the cost of central institutions needs to be explored.

5 References

[1] E. Durkheim, *The Elementary Forms of Religious Life*. Oxford University Press, 1912.

[2] A. Norenzayan, *Big gods: How religion transformed cooperation and conflict.* in Big gods: How religion transformed cooperation and conflict. Princeton, NJ, US: Princeton University Press, 2013, pp. xiii, 248.

[3] D. S. Wilson, *Darwin's Cathedral. Evolution, Religion, and the Nature of Society*. Chicago University Press, 2002.

[4] R. Sosis and C. Alcorta, "Signaling, solidarity, and the sacred: The evolution of religious behavior," *Evolutionary Anthropology: Issues, News, and Reviews*, vol. 12, no. 6, pp. 264–274, 2003, doi: https://doi.org/10.1002/evan.10120.

[5] B. Malinowski, R. Redfield, and J. P. Ascherl, *Magic, science and religion : and other essays*, Anchor books ed. in Doubleday anchor books. Garden City, N.Y.: Doubleday, 1954.

[6] V. R. Padgett and D. O. Jorgenson, "Superstition and economic threat: Germany, 1918–1940.," *Personality and Social Psychology Bulletin*, vol. 8, pp. 736–741, 1982, doi: 10.1177/0146167282084021.

[7] G. Keinan, "Effects of stress and tolerance of ambiguity on magical thinking.," *Journal of Personality and Social Psychology*, vol. 67, pp. 48–55, 1994, doi: 10.1037/0022-3514.67.1.48.

[8] A. Norenzayan and I. G. Hansen, "Belief in Supernatural Agents in the Face of Death," *Personality and Social Psychology Bulletin*, vol. 32, no. 2, pp. 174–187, 2006, doi: 10.1177/0146167205280251.

[9] G. Paul, "The Chronic Dependence of Popular Religiosity upon Dysfunctional Psychosociological Conditions," *Evolutionary Psychology*, vol. 7, no. 3, p. 147470490900700320, 2009, doi: 10.1177/147470490900700305.

[10] P. Norris and R. Inglehart, *Sacred and Secular: Religion and Politics Worldwide*. in Cambridge Studies in Social Theory, Religion and Politics. Cambridge University Press, 2004. doi: 10.1017/CBO9780511791017.

[11] K. Talmont-Kaminski, *Religion as Magical Ideology: How the Supernatural Reflects Rationality*, 1st edition. in Religion, Cognition and Culture. Routledge Taylor & Francis Group, 2013.

[12] W. D. Hamilton, “The genetical evolution of social behaviour. I.,” *Journal of theoretical Biology*, vol. 7, pp. 1–16, 1964.

[13] R. L. Trivers, “The evolution of reciprocal altruism,” *Quarterly Review of Biology*, vol. 46, pp. 35–57, 1971.

[14] D. Voas, “The Rise and Fall of Fuzzy Fidelity in Europe,” *European Sociological Review*, vol. 25, no. 2, pp. 155–168, Jul. 2008, doi: 10.1093/esr/jcn044.

[15] I. Puga-Gonzalez, F. L. Shults, G. Ross, and K. Talmont-Kaminski, “An agent-based model of prosocial equilibrium: Simulating the role of religiously motivated behavior in the formation and maintenance of large-scale societies.,” in *Advances in Social Simulation*, Milan, Italy: Springer, In press.

[16] S. Y. Diallo, R. Gore, C. J. Lynch, and J. J. Padilla, “Formal methods, statistical debugging and exploratory analysis in support of system development: Towards a verification and validation calculator tool,” *International Journal of Modeling, Simulation, and Scientific Computing*, vol. 07, no. 01, p. 1641001, 2016, doi: 10.1142/S1793962316410014.

[17] R. Gore, P. F. Reynolds Jr., D. Kamensky, S. Diallo, and J. Padilla, “Statistical Debugging for Simulations,” *ACM Trans. Model. Comput. Simul.*, vol. 25, no. 3, Apr. 2015, doi: 10.1145/2699722.

[18] R. J. Gore, C. J. Lynch, and H. Kavak, “Applying statistical debugging for enhanced trace validation of agent-based models,” *SIMULATION*, vol. 93, no. 4, pp. 273–284, 2017, doi: 10.1177/0037549716659707.