SECULARISM & NONRELIGION

RESEARCH ARTICLE

Post-Supernatural Cultures: There and Back Again

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The abandonment of supernatural religious beliefs and rituals seems to occur quite easily in some contexts, but post-supernaturalist cultures require a specific set of conditions that are difficult to produce and sustain on a large scale and thus are historically rare. Despite the worldwide resurgence of supernaturalist religion, some subcultures reliably produce people who deny the existence of supernatural entities. This social phenomenon has evoked competing explanations, many of which enjoy empirical support. We synthesize six of the most influential social-science explanations, demonstrating that they provide complementary perspectives on a complex causal architecture. We incorporate this theoretical synthesis into a computer simulation, identifying conditions under which the predominant attitude toward supernaturalism in a population shifts from acceptance to rejection (and vice versa). The model suggests that the conditions for producing widespread rejection of supernatural worldviews are highly specific and difficult to produce and sustain. When those conditions combine, which is historically rare, a stable social equilibrium emerges within which post-supernaturalist worldviews are widespread; however, this equilibrium is easier to disrupt than equilibria whose cohesion is stabilized by supernatural religion due to persistent cognitive tendencies toward supernaturalism in evolved human minds.

Introduction

In Scandinavian and Northern European nations today, as well as most coastal regions of the United States and many parts of Australia and New Zealand, a growing number of individuals do not believe in supernatural entities and reject religion in general. However, surveys show that supernatural beliefs are on the rise worldwide, an increase driven by resurgent religion in Africa, Asia, and most of the Americas (Berger 1999, Johnson 2010, Pew Research Center 2015). Why is widespread rejection of supernatural worldviews so rare, historically speaking? And what is so unusual about the social contexts within which post-supernaturalism becomes widespread?

Several social theories have attempted to describe pathways through which a culture can shift away from supernatural religiosity and toward post-supernaturalist secularity, many of which enjoy significant empirical support. After an exhaustive literature review, we identified the following six as being (1) the most influential, (2) the most relevant to interpreting the emergence and stabilization of post-supernatural cultures, and (3) the most empirically well supported.

· The Existential Security Path (e.g. Inglehart, Norris)
· The Cultural Particularity Path (e.g. Putnam, Campbell)
· The Human Development Path (e.g. Norris, Inglehart)
· The Meaning Maintenance Path (e.g. Berger)
· The Subjectivization Path (e.g. Heelas, Woodhead)
· The Supply-Side Path (e.g. Stark, Finke, Iannaccone)

Although some champions of these theories view them as inherently competitive or even mutually exclusive, we argue that these mainstream theories offer partial perspectives on a more complex architecture of causal factors driving changes in the religiosity and secularity of human populations. We are not alone. Ruiter and van Tubergen, for example, have attempted to show how (what we are calling) the existential security and supply-side paths can be "taken together" to "provide insights into differences in initial conditions, path dependency, and the reason why religious trends are sometimes reversed" (2009, p. 889). Probably the most ambitious attempt so far to produce a unified theoretical model is Stolz (2009), where correlations between aspects of some of the theories above (and some others) are explored using multi-level multiple regression modeling, though Stolz doesn't take account of post-supernaturalism as a dependent variable. Such integrative attempts are rare, and none developed to date illustrates concretely how the causal elements of all these theories can function together. It is important to note that we selected these six theories before trying to integrate them, and let the chips fall where they may as to whether integration would be possible and whether the meaning of the resulting synthesis would tell us anything interesting about transitions between supernatural religion and post-supernaturalist secularity.

We synthesize the core elements of these theories into a consistent conceptual architecture and implement the

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resulting model in a system-dynamics computer simulation. This allows us, first, to demonstrate the coherence of the synthesis, as implementation in a computational simulation imposes demanding requirements of conceptual clarity and consistency. The simulation also allows us to identify plausible conditions under which a population with a majority of individuals embracing supernatural beliefs (we will use *supernatural religious* to refer to this posture, which explicitly excludes naturalist forms of religion; again, the focus here is on supernaturalism, not religion) changes to a population in which most individuals have learned to contest inbuilt cognitive tendencies toward supernaturalism, thereby becoming "post-supernaturalists" (we will call this posture *post-supernatural secular*, referring both to personal views and to a corresponding form of socio-political organization where beliefs in and practices related to supernatural agents play no role; the unwieldy name is warranted to avoid confusion). The same simulation also indicates plausible conditions under which a society moves in the *opposite direction* (i.e. from post-supernaturalist secular to supernaturalist religious). Moreover, our computational model provides insight into the means by which supernatural religious coalitions and secular post-supernaturalist coalitions might inhibit or catalyze social transformation in either direction.

Computational modeling and simulation is a relatively new tool in social science, where it was introduced after it proved its worth in other fields, especially engineering (see a 2005 themed issue (110/4) of *American Journal of Sociology*, Iannaccone and Makowsky 2007, Squazzoni 2012). Simulation is a fruitful substitute for experimentation when (as with many social issues) experiments are impossible or unethical, the periods concerned are too long, or datasets spanning many decades are not available. Conceptually, computer simulation is not so different from demographic projection: both model a set of hypothetical scenarios by working out the implications of specific assumptions.

We refer to the computer simulation presented here as FOReST (an acronym for the "future of religious and secular transitions"). FOReST indicates that the conditions for producing widespread rejection of supernaturalist religion are highly specific, hard to produce, and difficult to sustain because they are individually necessary. When those necessary conditions combine, which is historically rare, there emerges a stable social equilibrium within which most people can contest maturationally natural cognitive tendencies to embrace supernatural thinking and behaving. Because it requires steady inputs of substantial energy to contest maturationally natural cognition and behavior, this post-supernatural social equilibrium may be easier to destabilize than more common social equilibria that take advantage of maturationally natural cognitive tendencies toward supernatural beliefs and practices.

Synthesizing Sociological Theories of Religious and Secular Change

FOReST is built on a causal model that synthesizes six empirically supported theories of secularization processes. As a simulation built upon these empirically well-grounded theories, FOReST provides a plausible model of the complex causal processes that underlie transitions from religious to secular and vice versa in actual human societies. Each theory synthesized represents a different "path" in our model (however, readers should be clear that our model is a systems-dynamic model, *not* a structural equation or path model, as previously used in the secularization literature). These paths—represented by differently colored arrows of causation in **Figure 1**—are explained
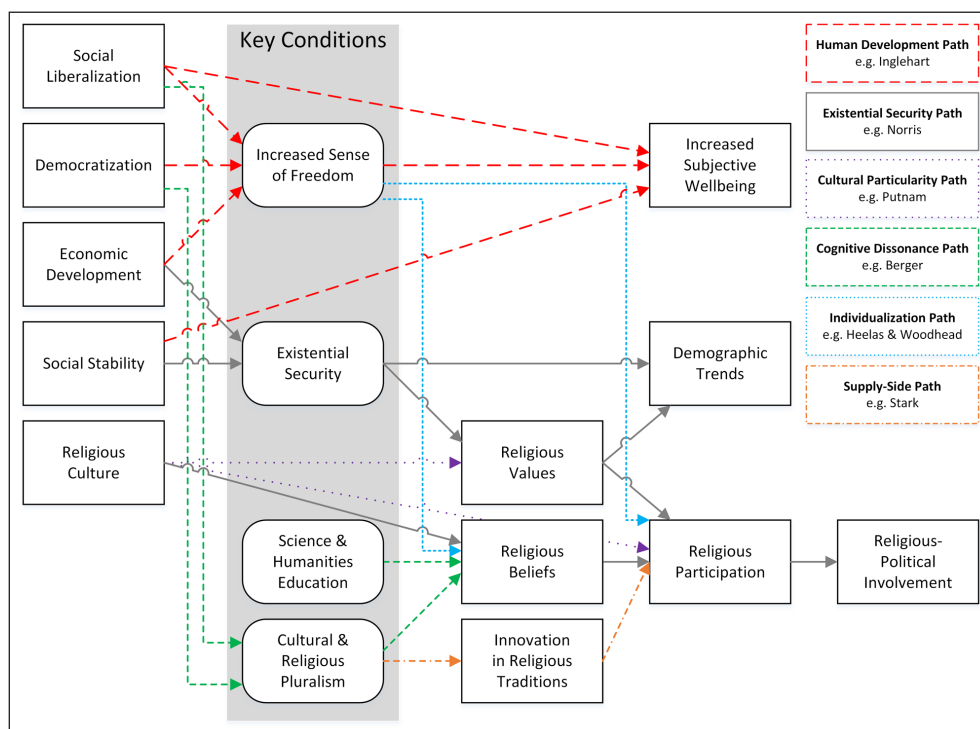

Figure 1: Conceptual model of synthesis of six theories of religious and secular change.

below. Inglehart et al. (2008) used "path" to refer to lines of society-level change in the direction of human development, inspired by the "paths" in the underlying structural-equation model that is incorporated into FOReST. We mean something similar, though with a different target: the six paths are lines of society-level change in the direction of decreasing or increasing prevalence of supernaturalism within a population.

The *Existential Security Path* is derived from theories rooted in data mined from the World Values Survey (WVS) and other datasets (e.g. Inglehart et al. 2008; Norris and Inglehart 2011; Inglehart and Norris 2012; Norris and Inglehart 2015; Norris and Inglehart 2019). According to Norris and Inglehart, differences in religious culture and changes in existential security predict shifts in personal religious values, beliefs, and behaviors. The Existential Security Path attempts to explain the way supernatural religiosity operates in a wide variety of cultural contexts, taking account of variations in religious cultures and demographics. It also tries to register the causally more determinate aspects of the effects of social change on religion (existential security changes religious values, which changes religious participation, which changes religiously motivated political involvement). Put simply, the basic argument here is that the more existentially secure a population feels the more likely belief in supernatural agents and participation in religious rituals will wane.

A second theory is expressed in what we are calling the *Cultural Particularity Path*. Here the focus is on the importance of particular religious cultures in determining religious values and religious participation. For example, Robert Putnam notes that the best predictor of religiousness in the United States is racial background (Putnam 2001; Putnam and Campbell 2010; Campbell and Putnam 2011a, 2011b). These insights are obviously based on considerations specific to one nation. From this point of view, looking for cross-cultural causal dynamics linking social change and supernatural religious beliefs and practices may be a quest merely to isolate minor influences on secularization rather than the most salient influences, the latter being more intricately tied to the historical details of each social setting. In plain language, demographic differences and sociological shifts of the sort described by Putnam and Campbell directly impact the rise or fall of supernatural religious values, beliefs, practices, and participation.

Third, the *Human Development Path* is based on a structural equation model (SEM) developed by Inglehart and Norris, utilizing WVS data (Inglehart and Norris 2012; Inglehart et al. 2008; Norris and Inglehart 2015). We were unable to replicate the SEM loadings for want of sufficient information about construct measures in the original calculations but the pathway makes solid theoretical sense and we incorporate it into the synthesis on that basis. This path indicates how four elements of social change (social liberalization, democratization, economic development, and social stability) produce an increased sense of freedom, which in turn increases subjective wellbeing. WVS data show that the most salient factor at the beginning of the Human Development Path is economic development, but with time economic development contributes less to subjective wellbeing than social liberalization and democratization. In other words, the processes that lead to the development of secularization begin with economic change and proceed (or intensify) with political and lifestyle change. Inglehart and Norris's original SEM standing behind the *Human Development Path* did not include social stability. We added social stability partly because it is an obviously relevant factor in individual freedom and subjective wellbeing, which decrease supernatural religious beliefs and practices, and partly because it helps us integrate the *Human Development Path* with the *Existential Security Path*. While much of the empirical warrant for these paths emerges out of analysis of similar datasets, the former path is more focused on freedom while the latter emphasizes the role of felt existential security.

A fourth family of theories is represented by the *Meaning Maintenance Path*, which is more directly informed by psychology than most sociological theories. Peter Berger's sociology of knowledge, for example, incorporates psychological concepts such as the need to relieve the pain of cognitive dissonance and the drive to create meaning (Berger 1969, 1973). Similar approaches can be found in the hypotheses set out by Proulx and Inzlicht (2012), which build on the work of Festinger (1957) and others. Such theories also give social meaning to psychological concepts such as plausibility structures of the sort that typically emerge as a result of education in the sciences and humanities, which tend to diminish supernatural religious beliefs (Hungerman 2014; Dyer and Hall 2019). This is one aspect of classical secularization theory that we should preserve because these psycho-social dynamics are demonstrably active in human affairs (for a defense of classical secularization theory, see Bruce 2011, ch. 2). Indeed, meaning maintenance and the management of cognitive dissonance have more recently become key concepts in cognitive science of religion, where they are incorporated into theories not only of the social and existential functions of religion but also of the evolutionary origins of religion (Guthrie 1993; Atran 2002).

The fifth pathway, the *Subjectivization Path*, is based upon the work of Paul Heelas and Linda Woodhead (Heelas and Woodhead 2000; Davie, Heelas, and Woodhead 2003; Woodhead and Heelas 2005). One of the most empirically sturdy results from these authors' research is that, as individual freedom increases, people become less wary of incurring social penalties when they express their spiritual beliefs and decide whether and how to participate in religious communities. In contexts where freedom of religious expression is strongly curtailed, on the other hand, the secularization process rarely gets started and people tend to continue believing in supernatural agents and engaging in supernatural rituals proscribed by the dominant culture. In other words, the extent to which beliefs about supernatural agents are "subjectified" (rather than institutionalized and monitored) impacts the extent to which individuals in a population maintain those beliefs and participate in traditional ritual practices associated with them.

The sixth and final path incorporated into our theoretical synthesis is meant to capture the insights of a family of supply-side sociological and economic theories (see, e.g., Stark and Iannaccone 1994, Finke and Stark 1998). We

call this the *Supply-Side Path*. These theories postulate a link between pluralistic cultural and religious settings and religious participation by means of competition-induced innovation in religious products (or services). This helps to explain why populations in some geographical regions tend to maintain the same basic levels of religiosity (or secularity) over time although individuals (with varying levels of religiosity or secularity) are constantly moving in and out of them (Iannaccone and Makowsky 2007). Such approaches are "supply side" (as opposed to "demand side") insofar as they argue that the dominant factors incrementing or decrementing religiosity have to do with the conditions and variables associated with the providers of religious services (as opposed to the needs of religious "customers"). We argue that some aspects of these supply-side theories can be understood as complementary to – and not only as competitors of – theories that emphasize the demand-side of religious participation.

Preserving the most empirically robust elements of each theory, we synthesized these six theories into a unified conceptual model that illustrates how those elements in the six theories are interconnected (**Figure 1**). FOReST has several feedback loops (illustrated in Supplementary Materials), so all variables interact. Nevertheless, we identify four variables (in the shaded area) as "key conditions" because they are salient mediators between generic socioeconomic conditions and supernatural religious or post-supernatural secular worldviews.

Constructing models is one thing; determining whether this synthesized causal architecture makes conceptual sense is another. Such a determination is dependent on the empirically validated theoretical arguments to which we have already alluded. Plausibility can also be increased by exposing this novel architecture to the conceptual rigors of implementation in a computational simulation. Building such a model demands precise specification of how the major components of the theory fit together. That process of clarification also requires us to make the model more specific in some places, and also to limit the scope of its applicability. One key to this is specifying the vague Religious Culture variable (**Figure 1**, lower left) so critical to the *Cultural Particularity Path*. We conceptualize this variable in a way that encompasses dynamics that tend to produce liberal religious cultures or conservative religious cultures. All details of the conceptual model are included in the Supplementary Materials.

Implementation in a System-Dynamics Computational Simulation

To analyze the processes that lead to changes between supernaturalist religion and post-supernaturalist secularism, we incorporated a conversion process into the synthesized causal architecture. The conversion process depicts post-supernaturalist secular and supernaturalist religious people being born and dying, and in between possibly converting from one posture to the other (Supplementary Materials contain detailed diagrams). People begin life either as supernaturalist religious babies or post-supernaturalist secular babies, corresponding to their dominant family and cultural heritage (these family and cultural relationships are implied, not explicitly incor-

porated into the model). Supernaturalist religious babies have three possible fates:

· They grow up to be supernaturalist religious adults without significant exposure to post-supernaturalist secularism.
· They grow up to be supernaturalist religious adults even though they receive significant exposure to post-supernaturalist secularism.
· They grow up to be post-supernaturalist secular adults because they receive significant exposure to post-supernaturalist secularism and actually convert.
· Likewise, post-supernaturalist secular babies may or may not be exposed to supernaturalist religion, and may or may not convert after exposure.

The way people move through the conversion process is affected by a series of flow rates, increasing or decreasing the corresponding direction of flow. Six key parameters in the conversion model determine flow rates, as follows.

· Religious Birth Rate (**RelBirthRate**): the birth rate of babies into supernaturalist religious family and cultural settings.
· Secular Birth Rate (**SecBirthRate**): the birth rate of babies into post-supernaturalist secular religious family and cultural settings.
· Exposure of Supernatural to Secular Rate (**ExposeToSecRate**): the percentage of supernaturalist religious people exposed in a substantive way to post-supernaturalist secularism.
· Exposure of Secular to Supernatural Rate (**ExposureToRelRate**): the percentage of post-supernaturalist secular people exposed in a substantive way to supernaturalist religion.
· Supernatural-to-Secular Conversion Rate (**ConvertToSecRate**): the percentage of supernaturalist religious people exposed to post-supernaturalist secularism who convert.
· Secular-to-Supernatural Conversion Rate (**ConvertToRelRate**): the percentage of post-supernaturalist secular people exposed to supernaturalist religion who convert.

This conversion model also includes a measure of Resource Scarcity (**ResourceScarcity**). This is impacted by the parameter Carrying Capacity (**CarryingCapacity**), which sets the total number of people possible in the ecology of the model. The Resource Scarcity variable is also affected by the actual population by means of feedback loops that drive the model dynamics.

Verification is an important phase of developing a system-dynamics computational simulation. One key question is: Does the expected range of behaviors emerge for appropriate flow-rate settings? For almost all settings of the six flow rates, this conversion process converges on an equilibrium state in which the ratio of supernaturalist religious people to post-supernaturalist secular people remains constant. The line graph in **Figure 2a** depicts the relative sizes of the supernaturalist religious (traditional) and post-supernaturalist (secular) subpopulations and
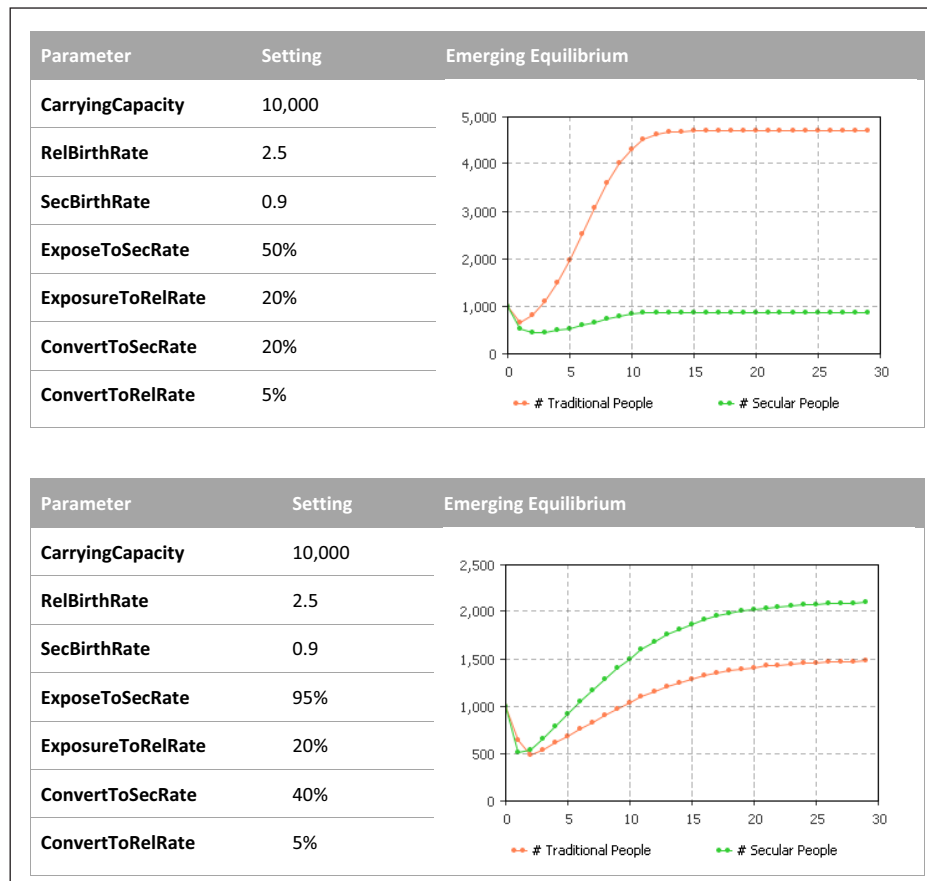
Parameter	Setting	Emerging Equilibrium
CarryingCapacity	10,000	
RelBirthRate	2.5	
SecBirthRate	0.9	
ExposeToSecRate	50%	
ExposureToRelRate	20%	
ConvertToSecRate	20%	
ConvertToRelRate	5%	

Parameter	Setting	Emerging Equilibrium
CarryingCapacity	10,000	
RelBirthRate	2.5	
SecBirthRate	0.9	
ExposeToSecRate	95%	
ExposureToRelRate	20%	
ConvertToSecRate	40%	
ConvertToRelRate	5%	

Figure 2: a (top): The conversion process shows an emerging equilibrium between supernatural religious (orange) and post-supernatural secular (green) people. The horizontal axis is model time. The vertical axis is the number of people of each type. The equilibrium depicts a social situation in which a small secular enclave exists within a larger supernatural population. **b (bottom):** The conversion model's emerging equilibrium with parameters set to yield more post-supernatural secular people than supernatural religious people. Only two parameters are changed between the two cases: the rate of exposure of supernatural religious people to post-supernatural secular worldviews (**ExposeToSecRate**) and the rate of **conversion** of supernatural religious people to post-supernatural secular worldviews (**ConvertToSecRate**).

displays the equilibrium as it emerges. To indicate how the conversion model works, suppose we set the six flow rates as in **Figure 2a**. The maximum supernaturalist religious birth rate (RelBirthRate) of 2.5 babies per person (the average is lower) and the average post-supernaturalist secular birthrate (SecBirthRate) of 0.9 babies per person along with the middling post-supernaturalist secular exposure rate (ExposureToSecRate) and conversion rate (ConvertToSecRate) suggest a social situation in which a small secular enclave exists within a larger supernaturalist population. **Figure 2b** shows a combination of parameter settings that yields an equilibrium state with more post-supernaturalist secular people than supernaturalist religious people. The social setting implied here is one in which virtually all supernaturalist religious people (95%) are exposed to secular modes of life and thought, and a sizable minority (40%) convert. The other rates remain unchanged from **Figure 2a**.

This verification exercise shows that the conversion model produces the expected behavior when we control flow rates *manually*. The next challenge is to define the six flow rates *automatically* using the causal architecture of religious and secular change described in the previous section. That is, the two birth rates, the two exposure rates,

and the two conversion rates are inferred from the theoretical synthesis of **Figure 1**. For example, the flow rate governing the extent to which supernatural religious people are exposed to post-supernatural secular worldviews is the average of technology, education, and pluralism (the way the flow rates are defined from the causal architecture is specified in Supplementary Materials). The result is dynamism: the population equilibrium changes as the six flow rates are altered by the causal architecture. To make the feedback system work, we feed the proportion of post-supernaturalist secular people from the conversion process back into the causal architecture, where it plays a critical role (again, see Supplementary Materials). Thus, the two-way conversion process stands in a feedback loop with the causal architecture derived from the conceptual model of **Figure 1**.

Most of the nodes (rectangles) in the top of **Figure 3** (inside the Causal Architecture box) match constructs in the conceptual model (**Figure 1**). There are some changes and additions to the nodes, all forced by the goal of implementing the theoretical synthesis of the causal architecture of religious and secular change in a coherent system-dynamics model. We explain these modifications along with all model details in the Supplementary Materials.
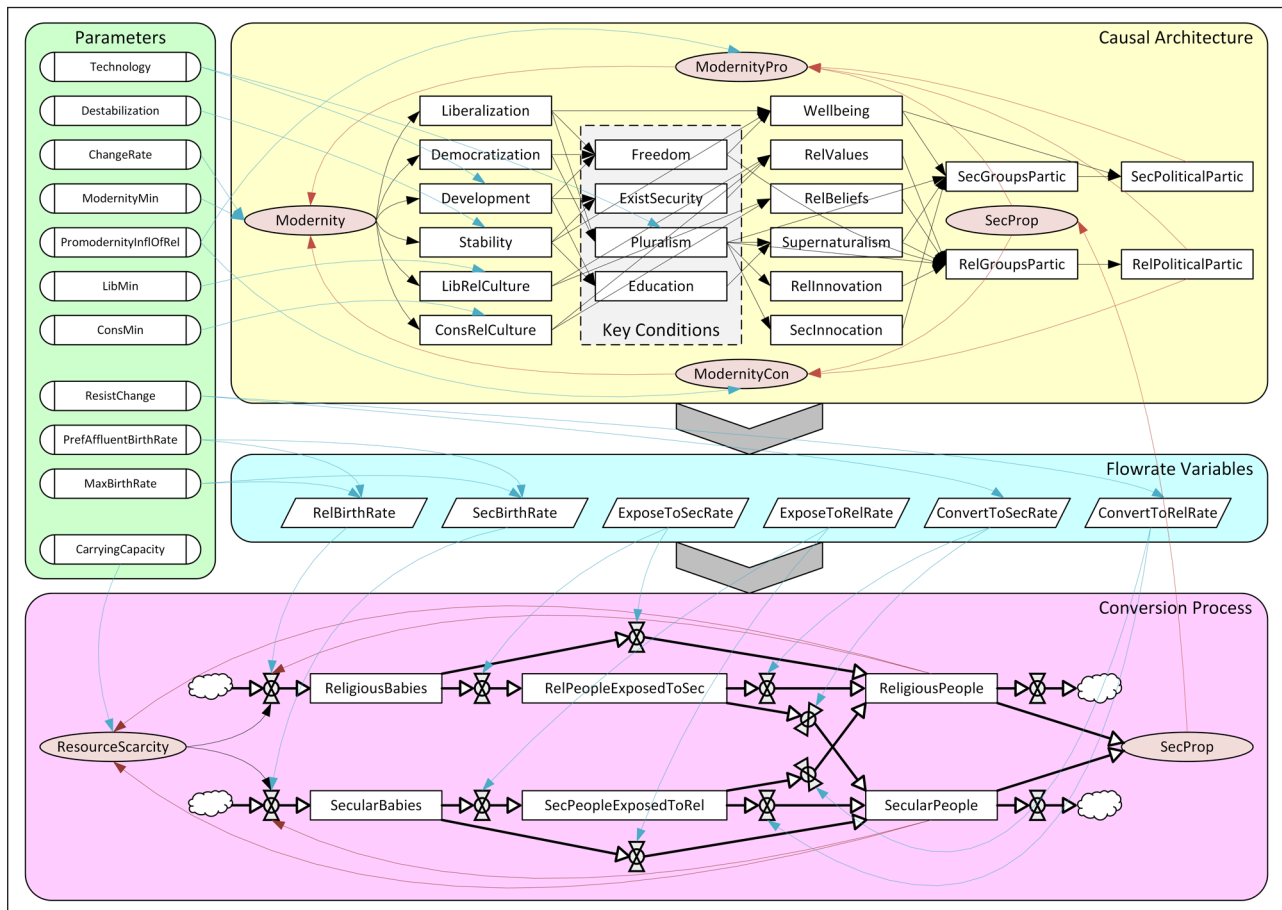
Figure 3: FOREST: The system-dynamics model using the causal architecture from the conceptual model of Figure 1 to derive flowrate variables needed to drive a conversion process back and forth between supernatural religious and post-supernatural secular outlooks. Parameters fixed for a given run of the simulation are arrayed along the left side of the figure. The conversion process is the bottom part of Figure 3. The six flow-rate variables driving the conversion process are in the middle part of Figure 3, fed by the top part and feeding into the bottom part. The four key conditions from the conceptual model (shaded in Figure 1) are lined up together in the middle of the causal architecture in the top part of Figure 3 and enclosed in a shaded box.

The main feedback loop in the top part of **Figure 3**, highlighted by red arrows, focuses on the Modernity variable (**Modernity**), which is a measure of the degree of "modernity" present in a social setting, and should be interpreted by how it influences liberalization, democratization, development, stability, and religious cultures (of liberal and conservative types). The Modernity variable is incremented by the Modernity Pro (**ModernityPro)** variable and decremented by the Modernity Con (**ModernityCon**) variable. These two variables sum the effects of the causal architecture that promote or suppress the emergence of characteristics of modern secular society, respectively.

The entire combined model has external parameters that typically stay fixed throughout a simulation run and effectively tune the model. Those parameters are arrayed on the left edge of **Figure 3** and are as follows.

- Technology (**Technology**): the technological capacity of the model world, which covers communication, transportation, agricultural, and manufacturing technologies.
- Destabilization (**Destabilization**): a quantified expression of disasters capable of destabilizing a social order (e.g. pandemics, environmental disasters,

nuclear war). If the destabilization parameter is above zero, wellbeing, existential security, and education are all negatively impacted.
- Rate of Social Change (**ChangeRate**): speeds up or slows down change in the Modernity variable.
- Lowest Threshold Possible for the Modernity Variable (**ModernityMin**): expresses the irreversibility of some degree of modern culture.
- Pro-Modernity Influence of Religion (**PromodernityInflOfRel**): reflects the fact that some supernaturalist religious beliefs and practices advance aspects of secular social life. For example, the booming Pentecostal movement in South America accelerates processes of liberalization and democratization, and the Protestant Reformation increased individualism and helped to give birth to Western modernity (see Bruce 2011).
- Lowest Threshold Possible for Liberal Religious Culture (**LibMin**): reflects the irrepressibility of liberal impulses to individual liberty, social justice, and human-heartedness.
- Lowest Threshold Possible for Conservative Religious Culture (**ConsMin**): reflects the portability of socially borne plausibility structures that keep supernaturalist

religious cultures alive regardless of how secular and post-supernaturalist the surrounding culture becomes.

· Preferred Affluent Birthrate (**PrefAfflBirthRate**; default is 0.9 babies per person, a little below replacement): expresses the preferred birth rate of people living with affluent levels of environmental calorie capture and is used to calculate religious and secular birthrates.

· Maximum Birthrate (**MaxBirthRate**; default maximum of 2.5 babies per person, with the average birth rate lower): is also used to calculate religious and secular birthrates.

· Resistance to Change (**ResistChange**): reflects the tendency of all people, and especially conservative people, to resist new ideas and experiences, and thus to resist conversion.

The formulas in the system-dynamics model of the causal architecture are as natural as possible (products are used when the input quantities are linked by a logical AND while averages are used when the link is a logical OR). Slightly more complex, but still natural, formulas express the way the Modernity Pro and Modernity Con variables are derived and how they in turn increment and decrement (respectively) the Modernity variable. The formulas for the six variables feeding into the conversion model express commonsense interpretations of the two birthrates, the two exposure rates, and the two conversion rates. Those details are also available in the Supplementary Materials.

Results

Using AnyLogic version 7 (The AnyLogic Company 2015), we ran this model through a parameter sweep. We used Latin Hypercube sampling to identify representative combinations of parameter settings. We recorded the associated emergent equilibrium (i.e. the proportion of post-supernatural secular people) for each combination of parameters and then analyzed the vast dataset of results to generate insights into model dynamics and to produce comprehensible visualizations of those dynamics.

Figure 4a and **4b** depict a response surface for the post-supernatural secular proportion of the population (**SecProp**). This response surface suggests that there are pathways leading to a population in which post-supernatural secularism becomes the dominant posture. A sensitivity analysis reveals that whether or not this transition occurs depends most strongly on high technology (the **Technology** parameter, which has a host of downstream consequences, including high ease of communication and population mobility, driving both pluralism and development upwards), and a high tendency among people with supernaturalist religious worldviews to create conditions conducive to the rise of post-supernaturalist secular people and societies (the **PromodernityInflOfRel** parameter; recall the examples of Latin American Pentecostalism increasing liberalization and democratization and Protestantism increasing individuality, thereby strengthening tendencies to Modernity). These pathways to the dominance of post-supernatural secularism are powerful enough to contend with the large disparity in birth rates, which were held at 0.9 for post-supernaturalist secular and significantly higher for supernaturalist religious people in the response surfaces of **Figure 4a** and **4b**.

As the level curves at the top of **Figure 4a** indicate, the post-supernatural secular population only goes past 50% if supernatural religious worldviews exercise a significant degree of influence (above about 0.5) in the direction of modern ways of life, other things being equal. Similarly, the proportion of the post-supernaturalist secular population can only rise above 50% when technology passes a threshold around 0.4. The same information is presented in an illuminatingly different way in **Figure 4b**. This time the vertical axis displays the absolute value of the
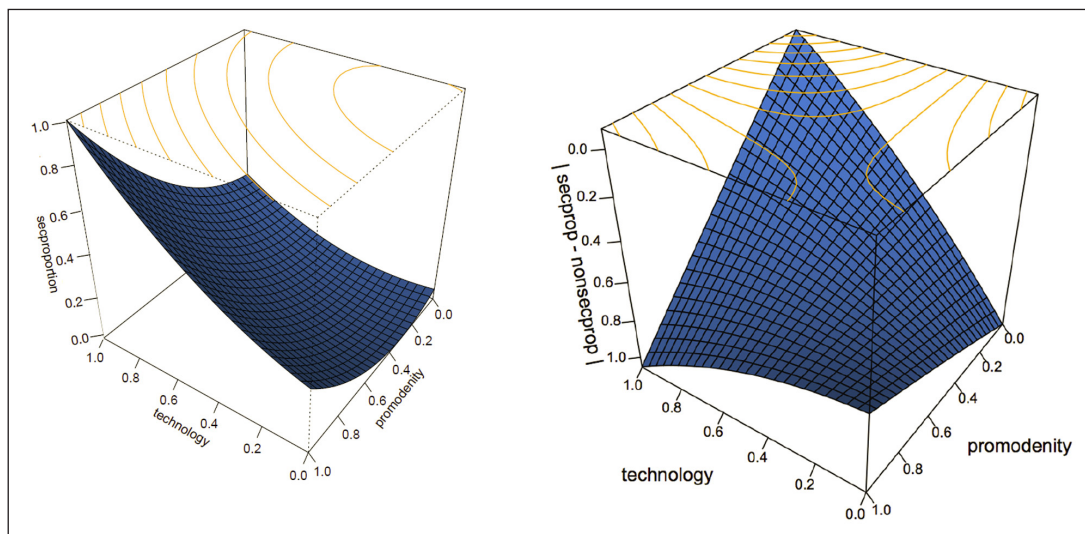

Figure 4: a (left): FOREST response surface for the proportion of the post-supernatural secular population as a function of the level of technology and the pro-modernity influence of supernatural religious worldviews. **b (right):** FOREST response surface for the difference between the proportion of the post-supernatural secular population and the proportion of the supernatural religious population as a function of the level of technology and the pro-modernity influence of religious worldviews.

difference between the post-supernatural secular proportion and the supernatural religious proportion of the population, while the other two axes remain the same. When that absolute-value number is zero, the population is at a 50–50 balance. At either side of the central ridge we see the two equilibrium regimes of the FOReST system: the historically common supernatural religious regime (on the right), and the historically rare post-supernatural secular regime (on the left).

The transition from the equilibrium regime of majority supernatural religious to the equilibrium regime of majority post-supernatural secular is the most interesting aspect of FOReST dynamics. It is difficult to perch the system at a 50–50 split; the model gravitates toward one of the stable equilibrium regimes. To examine this highly non-linear transition, we held all parameters constant except for technology (**Technology**), which we varied across its range (0 to 1). For each level of technology, we identified the equilibrium state. **Figure 5a** plots the equilibrium state for the post-supernaturalist secular (**SecProp**) and supernaturalist religious (**1−SecProp**) populations against the technology variable.

As technology increases, driving up many of the other variables in the causal architecture, the population balance shifts, with post-supernatural secular people growing in number but remaining a minority in the entire population. Eventually, however, a threshold is reached (in **Figure 5a**, around **Technology** = 0.5) after which there is rapid transition to a new equilibrium regime with post-supernatural secular people in the majority. **Figure 5b** shows actual population numbers instead of percentages, allowing us to see that a dominantly post-supernaturalist secular population produces a lower overall population (due to lower secular birthrates). The transition in the other direction, from a dominantly post-supernaturalist secular population to a dominantly supernaturalist religious population displays similar highly non-linear threshold behavior.

The dynamics of real-world social change are far more complex than can be expressed in a simple simulation such as FOReST. For example, system-dynamics models often involve two equilibrium regimes with high instability between them, whereas real-world social transitions between two equilibrium states is rarely precipitous. Nevertheless, **Figure 5a** and **5b** offer two insights into the dynamics of religious and nonreligious change. First, the transition from a dominantly supernatural religious to a dominantly post-supernatural secular population is a notably non-linear process in the model, which matches what happens in the real-world. In both cases, the change is gradual for a while but, when a threshold is passed, the entire society changes quickly to one in which supernatural religions are the special interest of a minority and the evolved tendencies to embrace supernatural worldviews are more widely contested within the culture. In the model, this is expressed in the "S"-shape of the transition curves of **Figure 5**, and the same type of transition was found in Brauer's (2018) study of a similar transition in the United States (not directly related to supernatural worldviews), and also in our own data on Norway, discussed in the Validation section below. Second, the fact that a dominantly post-supernatural secular population tends to be significantly smaller than a dominantly supernaturalist religious population will have important downstream implications for ecological sustainability, resource management, and economic practices.
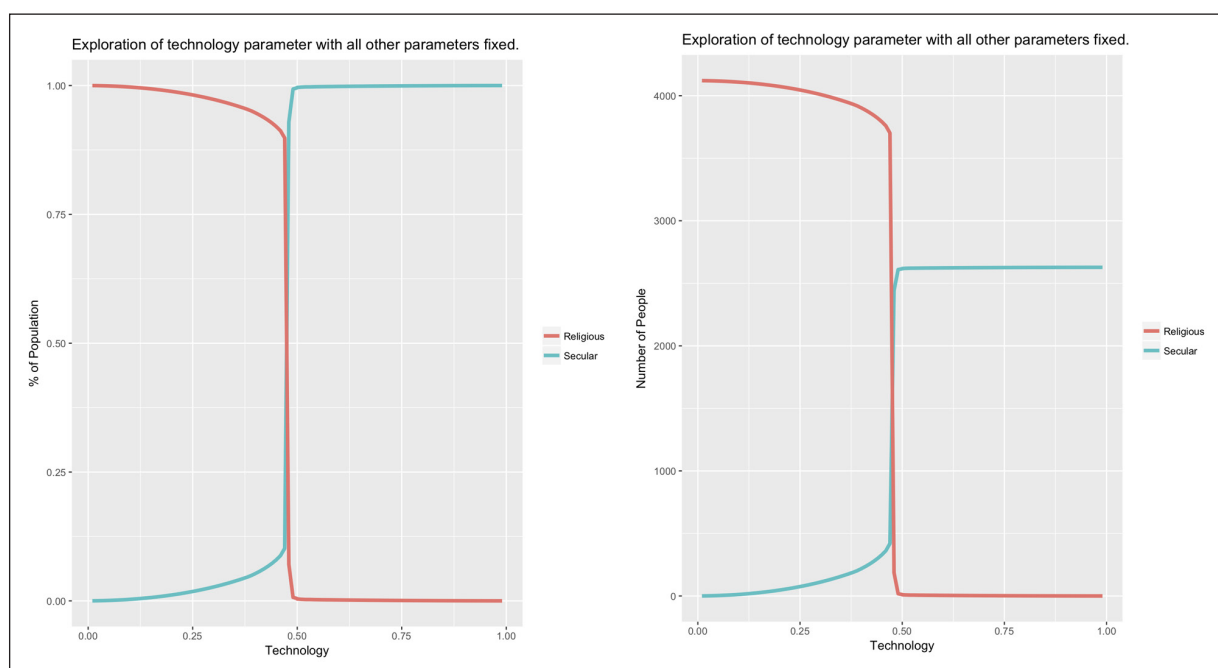

Figure 5: a (left): equilibrium state for the post-supernatural secular (**SecProp**) and supernatural religious (**1−SecProp**) populations plotted against the technology parameter, showing sensitive dependence on the technology at the boundary between the two equilibrium regimes. **b (right):** the same with population numbers instead of percentages, which shows that a dominantly post-supernatural secular population is much smaller overall, with important sustainability and ecological implications.
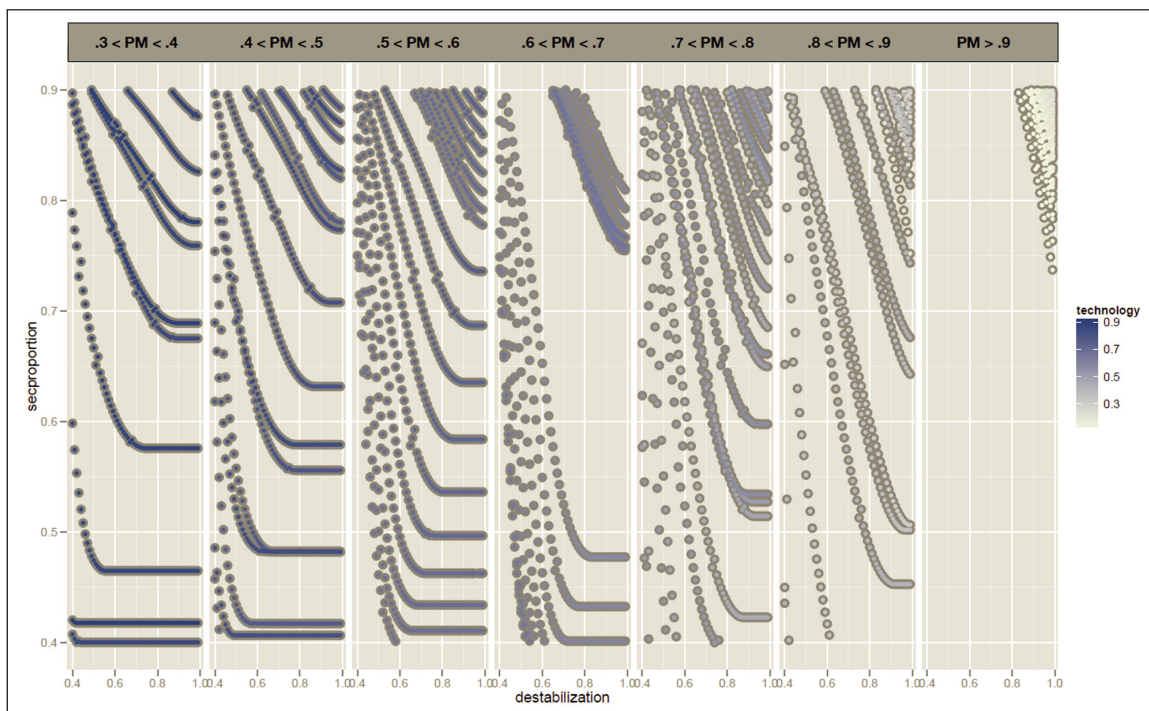
Figure 6: FOREST scatter plots illustrating the impact of the destabilization parameter (horizontal axis) on the proportion of post-supernatural secular people (vertical axis) for different levels of technology (color intensity) and the promodernity influence of supernatural religion (PM; in the panels).

The destabilization parameter (see upper left in **Figure 3**) is used to simulate the kind of disaster that could interfere with the key conditions under which a population moves in large numbers toward post-supernatural secularism. An increase in the destabilization parameter lowers wellbeing, existential security, and education. The effect of these dynamics is expressed through the series of plots in **Figure 6**. Each dot in **Figure 6** represents the equilibrium state achieved in one complete run of the FOReST simulation, with the proportion of post-supernatural secular people on the vertical axis, the destabilization parameter on the horizontal axis, the promodernity influence of supernaturalist religion (PM) determining the panels, and the color intensity expressing technology level. For middling values of the promodernity influence of supernatural religious worldviews (say, the third panel where 0.5 < PM < 0.6), destabilization clearly drives down the post-supernaturalist secular proportion in all cases, though least when technology remains relatively high and most when the level of technology itself falls.

This feature of the model shows that the conditions necessary for a majority post-supernatural secular population can be destabilized, after which the reverse transformation to a dominantly supernatural religious population can occur. This transformation is most dramatic when the disruption significantly reduces technological capability. This possibility of two-way traffic toward and away from post-supernaturalist secular worldviews and cultures is typically not envisaged within conventional secularization theory but it is a crucial aspect of FOReST.

We also ran simulation experiments to discover some of the conditions under which various levels of post-supernatural secularism emerge and persist. **Figure 7** indicates

that the proportion of post-supernatural secular people is low (0 to 30 percent) in societies when pluralism, security, or education are low, and when freedom is low to medium. Medium to high levels of security, education, and pluralism are conditions for achieving a 30–60 percent level of post-supernatural secular people. The percentage of post-supernatural secular people is high (60–90 percent) when pluralism, security, education, and pluralism are high. Only when all four variables (freedom, security, education, and pluralism) are very high do we find cases in which the proportion of post-supernatural secular people in a population is very high (90–100 percent); this is a rare situation even today.

Finally, we simulated the process of religious change over time, to identify the effects of the key conditions first for strengthening and then for weakening. **Figure 8** depicts the result, showing the number of supernatural religious people and post-supernatural secular people changing with the strength of key conditions over centuries (one model cycle per year) in a western nation that has navigated the transition (such as Norway) or is still navigating the transition (such as the USA). The timeline is established arbitrarily but made meaningful as a representation of change during the modern period by periodic increases in the technology parameter (every 75 years on average) while the simulation is running. For the first 400 years, key conditions strengthen (corresponding to the increasing technology parameter) and the religious population declines until it drops below the post-supernatural secular population, following an S-curve. At that point, the destabilization parameter is raised to a high level to simulate a civilization-damaging disaster, driving down the key conditions and eventually reversing the population distribution.
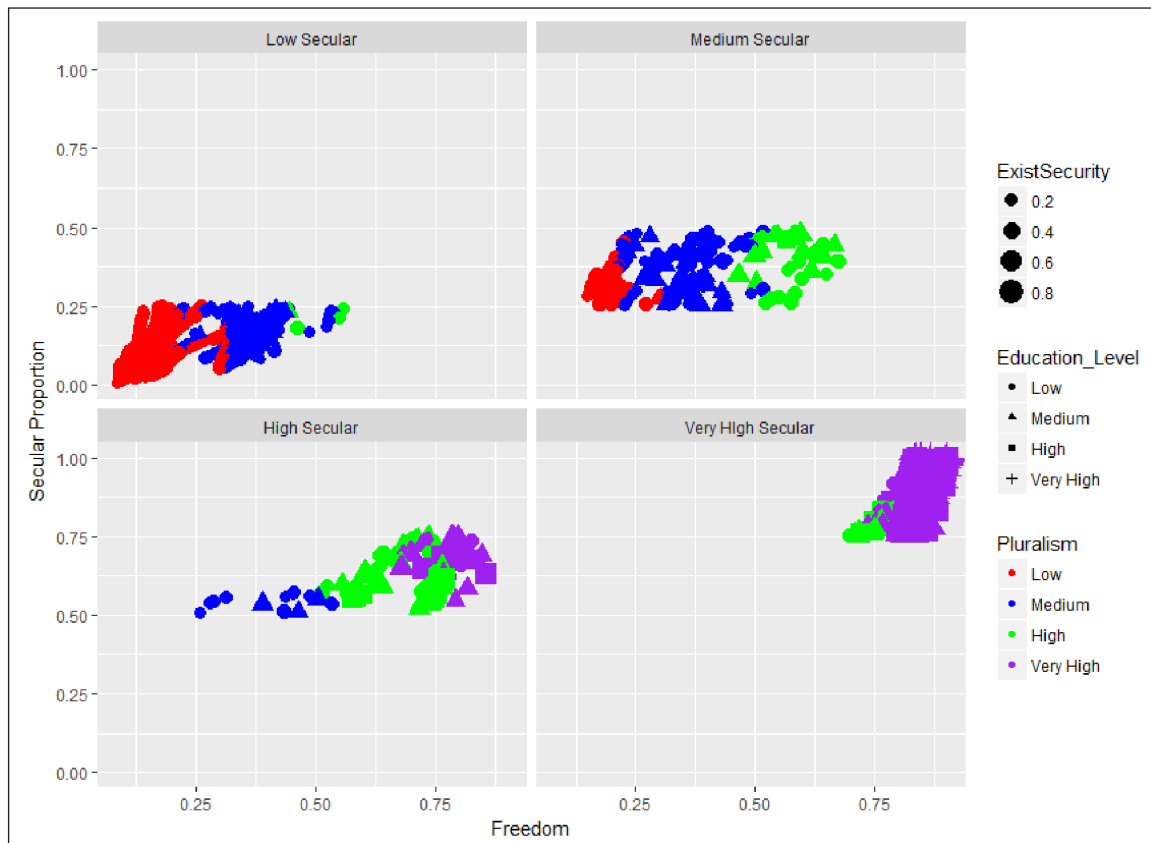
Figure 7: FOREST simulation results showing the conditions under which various levels of secularism emerge and persist in a population. The vertical axis of each panel is the proportion of secular people, and this same variable distinguishes the panels (the cut-offs for panels are 0.00, 0.25, 0.50, 0.75, 1.00). Freedom is on the horizontal axis, pluralism is color, education is shape, and existential security is size.
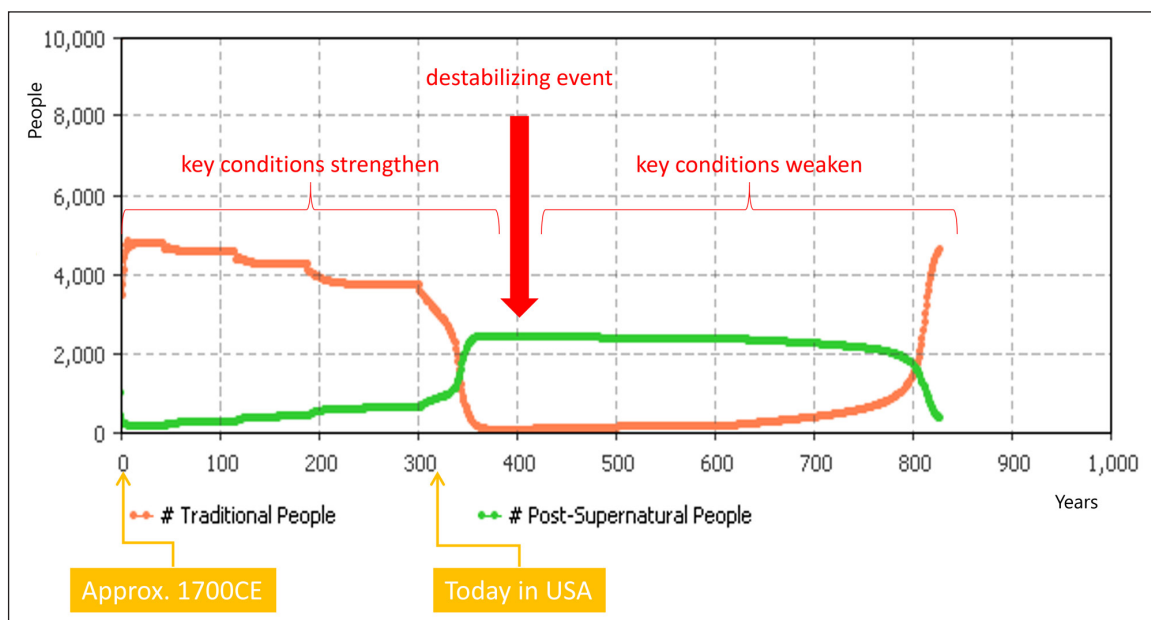

Figure 8: FOReST simulation results showing the effect of (1) strengthening key conditions (years 0–400) and (2) a destabilizing event that weakens key conditions (after year 400).

Validation

While this is fundamentally a theoretical research venture intended to illustrate an innovative method for exploring the dynamics of social change, we have also tried to validate the computational simulation to the extent pos-

sible (just as our group did in another model of religious change; see Gore et al., 2018). In seeking to validate FOReST against real-world data, however, we have been forced to acknowledge a serious difficulty. Data on most of the independent variables (parameters) is available for many

nations since 1900 or thereabouts. The data most difficult to find is longitudinal measures of the dependent variable, which is prevalence of supernatural worldviews – or, failing direct measures, reasonable proxies in the form of religious service attendance or private religious practices such as personal prayer. We have looked in vain for such data sources with the required longitudinal scope, ideally running back to the beginning of the twentieth century to cover the long transition process. We have concluded that survey data documenting the frequency of supernaturalist worldviews in a population over long periods of time does not exist for any country, including those such as Scandinavian nations that appear to have transitioned from dominantly supernatural religious worldviews to dominantly post-supernatural secular worldviews.

Data on *religious affiliation* for the last 120 years exists for several national settings but affiliation is not what matters in FOReST. In Norway, for example, the very large majority of people currently self-identify as Christian on census forms but the level of regular religious service attendance is extremely low. If David Voas (2009) is correct about his "fuzzy fidelity" thesis – and Brauer's (2018) analysis certainly suggests that Voas is onto something important with his claim that different aspects of religiosity change at different speeds – we would expect official religious self-identification to *mask the underlying dynamics of change* in religious and nonreligious worldviews and practices.

Going beyond census religious identification, measures of personal religious faith, religious service attendance, private religious practices, and orthodoxy of religious belief do exist, fragmentarily, for some time periods within deeply secularized countries. However, none of these four is a close proxy for the prevalence of supernaturalism because evolutionarily stabilized tendencies in human cognition can sustain supernatural worldviews even when traditional religion is rejected. Hopefully data on service attendance, religious beliefs, private religious practices, and orthodoxy of religious beliefs, which has

been collected for the past few decades in several national settings, will eventually accumulate to make analyzing the staggered dynamics of religious and nonreligious change possible for countries such as Norway where the post-supernatural secular transition is far along; for national settings such as the USA, which are not as far along in the secularization transition; and for national settings undergoing transition in the opposite direction. Even then, however, we would still not have a direct measure of the dependent variable we most need to evaluate FOReST in detail, namely, prevalence of supernatural worldviews. Very few surveys have attempted to measure supernaturalism on the scale of a population and almost none has any longitudinal depth. We are hopeful that the New Zealand Attitudes and Values Study, a longitudinal cohort study, will accumulate enough waves of the right kind of data to allow us to construct a dataset useful for validating FOReST (see New Zealand Attitudes and Values Study 2020).

Ultimately we decided to create a novel dataset by asking four experts in the modern history of religion in Norway to graph the prevalence of five dimensions of religiosity: personal religious faith, religious service participation, private religious practices, orthodoxy of religious beliefs, and prevalence of supernatural worldviews (the one of immediate interest to us) in that country from 1900 to 2020. The data we collected, along with longitudinal census data on religious identification, is summarized in **Figure 9**. The results suggest that (1) Norway has in fact transitioned from supernaturalism as a majority worldview to supernaturalism as a minority worldview; (2) the transition takes the form of an "S" curve, with slow decrease as supernaturalism remains dominant but decreases in prevalence, followed by a period of more rapid decrease through the critical majority-minority 50% level, followed in turn by a period of slow decrease as supernaturalism becomes increasingly uncommon; and (3) none of the five potential proxies for supernaturalism is ideal, with census data (the easiest to obtain over a long
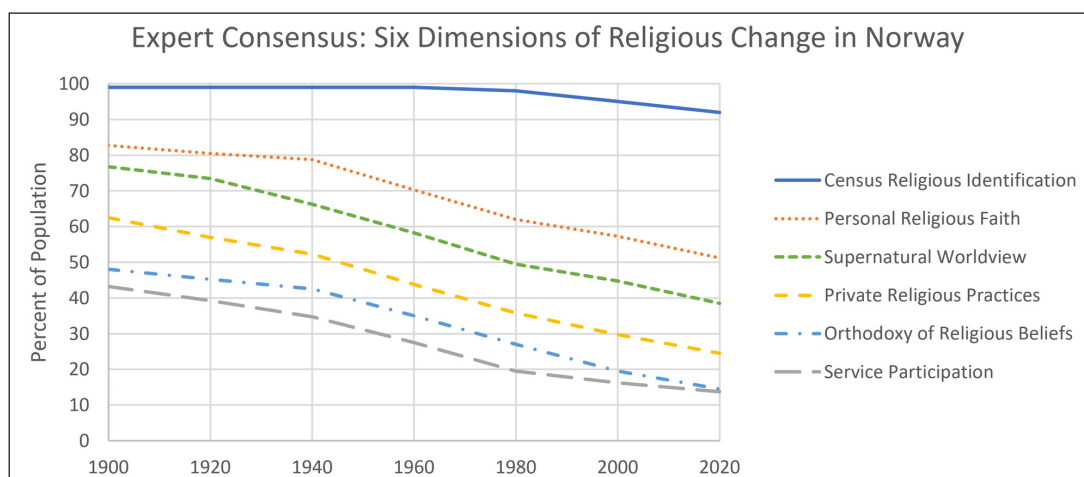

Figure 9: A summary of the consensus of four experts in modern religious history of Norway, estimating the change in six dimensions of religiosity over the last 120 years. Note the S-curve transition with the slope steepest in decades immediately following World War II (ended in 1945). Also note that, for this group of experts, the average of Personal Religious Faith and Private Religious Practices serves as a reasonable proxy for the estimated level of supernatural worldviews.

period of time) being the worst and an average of personal religious self-identification and private religious practices being the best.

We use this expert-opinion dataset to validate *qualitatively* the transition dynamics on display in the computational simulation (i.e. comparing **Figure 8** and **Figure 9**). In both cases, passing through the 50% prevalence mark, the supernatural worldview curve has the steepest slope, indicating a gentle S-curve, so the expert consensus matches the geometry of the FOReST transition in **Figure 8**, as well as the findings of Brauer (2018) for the same transition in the United States.

The reason social scientists have not measured the prevalence of supernatural worldviews until very recently is worth noting. The importance of supernatural worldviews as a psychological construct only became evident with the advent of experiments in the cognitive science of religion demonstrating the presence in our species of a powerful cross-cultural tendency toward preferring supernatural explanations; McCauley (2011) describes supernaturalism as "maturationally natural" for our species. The maturational naturalness of the tendency to embrace supernaturalism makes it difficult for most individuals to change but it can be contested effectively, under certain circumstances (which FOReST identifies, by consolidating the six underlying theoretical pathways of religious and nonreligious change).

Figure 9 also presents the best simple proxy we could construct from the data we collected as an approximation to the expert estimates of the prevalence of supernatural worldviews, namely, the average of personal religious faith and private religious practices. The possibility that we may be able to derive a rough proxy from measures that have been collected more frequently than prevalence of supernatural worldviews is promising for future validation efforts of models seeking to explain the transition from supernatural religious cultures to post-supernatural secular cultures. Of course, the candidate proxy itself would need to be validated in other settings and using different methodologies.

Discussion

The results of the FOReST simulation indicate that several conditions must hold for most people in a population to embrace a post-supernatural secular worldview and way of life. Though all variables interact because of feedback loops, we highlight the four most theoretically salient factors using the shaded box in **Figure 1** and again at the top of **Figure 3**. The dynamics connected with these key variables are part of a complex system of interactions, but we can distinguish their effects.

· Heightened existential security, driven by effective economic and social practices, undermines the need to seek protection from supernatural agents and coalitions, decreasing the appeal of supernatural religious worldviews and increasing post-supernatural secularism.
· Heightened freedom of self-expression weakens the power of social prohibitions against acting on personal convictions, removing economic and social penalties

for both supernatural religious and post-supernatural secular forms of personal self-identification.
· Heightened scientific education erodes the plausibility structures that support supernatural religious worldviews, while heightened humanistic education reinforces appreciation for the value of human questing and the feasibility of post-supernatural secular forms of social organization.
· Heightened pluralistic attitudes to cultural diversity diminish the plausibility of all exclusivist, supernaturally authorized coalitions. Cultural pluralism, which is perhaps the most significant factor contributing to the extraordinary period of transformation we call modernity, has led to a global conversation about religion across cultural boundaries, rendering permeable almost all formerly internally incorrigible supernatural worldviews.

In the model, these conditions are strengthened when there is advanced technology, when there is high energy capture (efficient extraction of energy from the environment for food and culture), and when cultural history has produced dominant religious outlooks that foster the emergence of secular forms of socio-political organization and high levels of scientific and humanities education. This latter point is particularly important: some supernatural religions help to give birth to the very conditions that undermine the supernatural worldviews on which traditional religious narratives depend. This point has been persuasively argued on historical grounds (Buckley 1987) and is built into the model's Pro-Modernity Influence of Religion (**PromodernityInflOfRel**) parameter.

Important consequences flow from the identification of these four key conditions. Someone opposed to the emergence of a social order in which most of the population holds a post-supernatural secular worldview could be inspired by the findings of FOReST to generate strategies intended to avoid or weaken such an order. Relevant resistance strategies could include ensuring that children are educated locally, under the control of school boards that can suppress an accurate understanding of cosmology or evolution; that plausibility structures remain strong within active and vibrant religious communities, so that exclusivist attitudes to religious authority can be convincingly sustained; that social media and news outlets should be so fragmented that isolated communication flows can sustain the persuasiveness of supernatural outlooks without having to confront types of discourse that undermine those outlooks; and that social disincentives to leave a religious community are as large as legally possible, which is easiest to achieve outside of large cosmopolitan population centers in small-town settings. A more aggressive approach is also possible, seeking to overthrow modernity entirely, as the violent Islamic State of Iraq and the Levant (ISIL) aspires to do. Social destabilization on a scale sufficient to decrease the availability of high technology (and thereby block its downstream consequences for existential security, freedom, education, and pluralism) should be enough to reverse the trend toward post-supernatural secularism. By contrast, someone who favored a post-supernatural secular worldview would have

to be on guard for precisely those kinds of destabilization maneuvers and work hard to preserve the conditions necessary for the training of each new generation of children in how to contest the maturationally natural embrace of supernatural religious beliefs and behaviors.

Importantly, these four key conditions also create challenges and opportunities for extant religious traditions, placing pressure on supernatural beliefs and practices as well as presumably opening vectors for internal institutional transformation in the direction of post-supernatural religious outlooks. Some religious communities may embrace the changing plausibility structures instead of resisting them, which would lead to revised conceptions of religion as post-supernaturalist. If the supply-side path has anything to commend it, and we think the empirical evidence suggests that it does, then we should expect religious communities in some contexts to adapt to changing worldviews, moving in a post-supernatural direction rather than standing idly by while more and more people defect. The movement of religious naturalists – those who reject supernaturalism and religious authoritarianism and yet still detect worship-worthy spiritual depths in reality – appears to be growing (for example, see ReligiousNaturalism.org). Similarly, new religious groups that are secular and spiritual yet strongly post-supernaturalist and decidedly not traditionally religious are springing up everywhere (Heelas and Woodhead 2005; Langston et al. 2015).

Post-supernatural secular worldviews (as against secular forms of social organization) have probably always existed alongside supernatural religious postures as a minority position within the population. However, explicitly post-supernatural secular worldviews were never dominant in any civilization throughout human history until recent decades. What does the future hold, barring the kind of destabilizing ecological or technological disaster that FOReST suggests might trigger reversion to supernatural religious cultures? A key question here is how stable a social order could be when secular rather than religious people are in the large majority.

The FOReST model indicates that it is difficult to produce and sustain a population in which post-supernatural secular postures are dominant because the relevant conditions require a high level of energy input to the social system. Existential security can only remain high if energy capture is high and deprivation conditions are eliminated. Free self-expression requires technology and political practices that are robust enough to hold out against the chaos of individual opinions and the pernicious truth-denial of social-media mayhem. Educational processes must train students how to overcome inborn cognitive biases toward supernaturalism. Cultural diversity must be welcomed rather than avoided. All of that takes energy captured from the natural environment and spent to sustain the form of social organization, and the training of human beings to embrace ways of thought and action that are in some ways contrary to what is maturationally natural for them.

Because of this need for energy input to stabilize the post-supernatural social equilibrium, it is reasonable to suppose that a post-supernatural secular social order might be more vulnerable to catastrophic collapse. If even one of these conditions (high existential security, high free self-expression, high education, high cultural pluralism) begins to disintegrate, people find it more difficult to contest the evolved proclivities that have fostered majority-supernatural religious social orders. Each new child is born into this world with similar cognitive-emotional mechanisms and it is only neural plasticity and cultural entrainment that make it possible for a child to learn how to contest those tendencies, many of which all too easily lead to error (McCauley 2011). If a post-supernatural secular social order destabilizes to the point that existential security is threatened, for example, then the entire system can revert to the civilizational form that has characterized most of human history: the dominance of supernatural religious worldviews and the sequestering of non-supernatural outlooks to the margins of the social order. **Figure 6** suggests that the reversion transformation might be more or less dramatic, depending on other factors.

As we noted in the Introduction, post-supernaturalist secular postures (and a variety of forms of emergent social structures to support them) have expanded in Scandinavia and several other regions around the world (Zuckerman 2008, 2016). On the other hand, where *any one of the four primary conditions* for the emergence of a post-supernatural era is absent—that is, when existential security, personal freedom, education, *or* pluralism is low—supernaturalism still dominates the religious and spiritual imaginations of the prevailing social order. This could help to explain why the USA has moved more slowly toward secularism than Northern Europe and most other North Atlantic cultures: even though three of the four conditions are strongly present, the USA's education system is largely regulated locally, preventing it from having the effects that high levels of scientific and humanities education have had in other, more secularized cultures. The fact that a large majority of people in the USA reject the scientific consensus of evolutionary theory (Pew Research Center 2014) shows how effective the weakening of just one of the four necessary conditions can be in arresting the transformation in the direction of a dominantly post-supernatural secular population.

Conclusion

The point of FOReST and of this paper is theoretical in nature, seeking to demonstrate the possibility and usefulness of a synthesis of social-science theories of supernatural religious and post-supernatural secular transitions and to identify the key factors that determine how these transitions unfold. We have not attempted to argue about the relative value of the supernatural religious posture that has long dominated human life in comparison to the post-supernatural secular posture that is expanding in some parts of the world in recent years. Rather, we have tried to show that the theoretical integration and causal architecture of the FOReST model does a serviceable job of explaining the *two-way transition dynamics* between populations that are primarily supernatural and those that are primarily post-supernatural. The FOReST model

helps to explain why secular cultures dominated by individuals with non-supernatural worldviews have been so rare in the history of human civilizations, and it illuminates the pathways by which cultures can get there – and back again.

Additional File

The additional file for this article can be found as follows:

· **Supplemental Material.** AnyLogic source code for the FOReST model. https://github.com/centerformindandculture/FOReST.

Competing Interests

The authors have no competing interests to declare.

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