The Macroeconomics of Pascal's Wager

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Abstract

This paper explores the determinants of religiosity in a growth model. Religion reduces the time available for labor and the perceived likelihood of hell. A genetic algorithm selects agents' discount factors based on their parents' wealth. A higher discount factor increases savings, encouraging wealth accumulation, but also increases the discounted disutility of eternal damnation, incentivizing religion. The model converges to intermediate levels of the discount factor and religion where wealth is maximized. The genetic process selects agents' level of patience and the impact on religion is a side effect. Religion thus exists in equilibrium, even if it reduces genetic fitness.

JEL Classification: religion, genetic algorithm, learning.

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1 Introduction

In 1670, the French philosopher Blaise Pascal posthumously published his famous argument in support of a religious lifestyle in the text *Pensees*. Pascal's Wager posits that if one is uncertain about the existence of an afterlife, then it is rational for her to choose to be religious. If she chooses to be religious and is wrong, then she faces no negative consequences after her death. If she chooses to be non-religious and is mistaken, however, then she forgoes salvation and instead risks eternal damnation. Several interesting criticisms have been made against Pascal's Wager including that God does not care about the specific belief, only that it be sincerely held, that religion is not a choice, and that the probability of God existing is zero [Hajek 2003]. The general idea is, however, reasonable from the perspective of a rational expected utility maximizing agent.[1]

From a macroeconomic perspective, Pascal's Wager has one important flaw: the idea that eternal damnation (including the opportunity cost of salvation) results in an infinite welfare loss. Continuity of preferences suggests that a rational agent would be willing to swim in a lake of molten hellfire, provided that it cause no lasting damage, for a very small but positive amount of time in exchange for some earthly pleasure. The instantaneous welfare loss of hell is thus finite. Another example comes from Dante's *The Divine Comedy*, arguably the most famous depiction of hell. Dante's Inferno includes nine, increasingly unpleasant, circles of hell, which requires that at least the first eight result in finite disutility. If agents use a discount factor less than one, then hell is an infinite geometric series that converges to a finite level of disutility which is increasing in the discount factor. Although there are other arguments for why the disutility of hell is finite [Hajek (2003)], I am unaware any prior work that bases this argument on discounting.

This paper adds Pascal's Wager to a very long run growth model where time allocated to religion reduces the time that is available for production, and where agents' preferences evolve based on a genetic learning algorithm.[2] I then examine the joint determination of religion, wealth, and agents' discount factors. The main result is that that agents choose a level of religion greater than the amount which, all else equal, maximizes their evolutionary fitness. Furthermore, the resulting discount factor is less than the value that maximizes evolutionary fitness in a model without religion.

The model is best suited for a pre-industrial economy. In such a setting, standard theory suggests that evolution favors the prosperous. Skjaervo, *et. al.* [2011] write that "wealth and status covary with lifetime reproductive success in pre-industrial human populations." Skjaervo and Roskaft [2015] further find that wealth promotes fitness primarily by making widowed spouses more likely to remarry. Malthusian theory posits that increases in wealth led to increases in population that allowed per-capita income to remain stable in the longterm. Although there has been much speculation that this relationship may no longer hold in modern societies, Nettle and Pollet [2008] show that while more education reduces the number of offspring, increased wealth continues to result in more offspring.

Religion poses obvious economic costs. Time devoted to worship, prayer, preaching, etc. could be used to produce and thus increase one's genetic fitness. Churches could be converted into farms or factories, and animals could be bred or consumed instead of being used for sacrifice. Why evolution has not therefore selected less religious agents is a puzzle that has attracted the interest of the public, biologists, and economists. A major literature proposes that evolution does directly select more religious agents and seeks to identify subtle evolutionary benefits of religion that trump the obvious costs. Much of this literature in in evolutionary biology. Hamer [2005] suggests that the evolutionary benefits of religion may include reduced stress, increased optimism, and the ability to overcome setbacks.[3] His work resulted in a *Time Magazine* cover story titled "the God Gene."[4] Hill and Pargament [2003] argue that religion may improve both physical and mental health. Other arguments consider group selection, where religion increases social cohesiveness or deters disruptive behavior.[5] Stark [1997], for example, proposes that religion may act as a method of community risk sharing.

Economics has also proposed scenarios where religion may yield net economic benefits. Barro [2004] writes that religion may be seen as "spiritual capital," which encourages attributes "such as honesty, work ethic, thrift, and openness to strangers." Berman [2000] develops a model where high levels of religion "signals commitment to the community, which provides mutual insurance to members." Iannaccone [1992] models religion as a "club good" where seemingly irrational rituals and behavior serve to prevent individuals from joining who then choose minimal involvement. Berman and Iannaccone (2006) suggest that religious sects may efficiently provide social services when governments fail. In his survey of the economics of religion, Iannaccone (1998) notes that many religions prohibit unhealthy behaviors such as drinking, smoking, and the use of illicit drugs. In an empirical study, MacCulloch and Pezzeini [2010] find that religion may reduce the propensity for revolutionary tastes.

This paper's results are compatible with all of these theories which suggest a direct evolutionary advantage to religion. Section 4 considers a version of the model where religion enters the production function, thus directly benefiting wealth and genetic fitness. The mechanism of this paper, where patience and religiosity co-evolve, then causes *additional* religious activity beyond the level which maximizes wealth and fitness.

I rely on a genetic learning algorithm that determines only one parameter, the discount factor, and does not directly consider religion. The wealthier the agent, the more likely that she successfully reproduces. I use a simple growth model where agents maximize their utility, not their evolutionary fitness. In addition to choosing their savings rate, agents also choose how much of their time to devote to religious activities. More religion reduces the time that an agent may spend producing and therefore reduces their wealth and probability of reproducing. More religion also reduces the perceived probability of eternal damnation, but this has no direct effect on reproduction.

As in most growth models, a higher discount factor induces a higher savings rate that, all else equal, increases wealth. If the average discount factor is initially very low, then the discounted value of everlasting hellfire is also low and the population will choose a low level of religion. Low discount factors deter savings and wealth accumulation, and the net economic benefits of a higher discount factor are positive. Through reproduction, mutation and other operators, the genetic algorithm selects agents with higher discount factors and more wealth. As the average discount factor increases, however, so does the discounted cost of hell. Agents thus choose more religion even though, all else equal, religion reduces evolutionary fitness. Crucially, the genetic learning algorithm is not selecting more religion, it is selecting a higher discount factor. Increased religion is a side effect. Gould and Lewontin [1979] refer to this type of result as a "spandrel," defined as a byproduct of evolution rather than a direct result of it.

The dynamics of the model also work in the opposite direction. Suppose that all agents have discount factors just below one. The cost of hell is therefore exceptionally large. Agents rationally choose to devote most of their time to religion, and their wealth and genetic fitness suffer. In this case, the genetic learning algorithm selects a lower discount factor.

A society's religious fervor depends both on the strength of its convictions and the consequences of disbelief. Increasing either parameter increases the equilibrium level of religion, and reduces the average level of wealth. The genetic algorithm thus selects a lower average discount factor, which mitigates the economic costs of heightened religiosity. The model thus predicts that more religious societies exhibit less patience and less wealth once convergence has occurred.

I also consider the impact of a shock to religious beliefs. When they become less intense, agents respond by immediately spending less time on religion. Afterwards, the genetic algorithm selects for more patient agents, which then allows religion to partially recover towards its initial levels. The short run impact on religious activity thus overshoots the ling run effect.

The paper is organized as follows. Section 2 develops a simple growth model. Section 3 develops the genetic learning algorithm. Section 4 discusses simulations that demonstrate the model's dynamics. Section 5 discusses potential extensions and concludes.

2 A Simple Growth Model

To make the paper's main mechanism clear, I rely on a very simple growth model that includes religion. Agents live for two periods but solve an infinite horizon problem that accounts for the possibility of an afterlife. In the first period, agents choose their savings, and allocate their time between labor and religion. Adding a leisure choice to the model does not affect any of this paper's main results. In the second period, agents live off their savings and do not choose how they allocate their time.[6] I define κ as the perceived probability that an afterlife exists, and Ω as the per-period instantaneous disutility of being in hell compared to heaven. The expected present discounted value of damnation thus equals $\frac{\kappa\Omega\beta_{i,t}^2}{1-\beta_{i,t}}$. Notably the individual parameters κ and Ω are not identified, only the compound parameter $\kappa\Omega$, the expected disutility of hell, is. The i^{th} household solves the following optimization problem:

$$Max_{C_{i,t},L_{i,t},R_{i,t}} \quad \frac{C_{i,t}^{1-\sigma}}{1-\sigma} + \beta_{i,t}\frac{C_{i,t+1}^{1-\sigma}}{1-\sigma} + \tau(R_{i,t})\frac{\kappa\Omega\beta_{i,t}^2}{1-\beta_{i,t}} \tag{1}$$

$$N_{i,t} + R_{i,t} = 1 \tag{2}$$

$$W_{i,t+1} = (N_{i,t}^{\alpha} - C_{i,t}) \tag{3}$$

$$W_{i,t+1} = C_{i,t+1} \tag{4}$$

The household allocates one unit of time between labor ($N_{i,t}$) and religion ($R_{i,t}$). Production is determined by a Cobb-Douglas production function where $Y_{i,t+1} = N_{i,t}^{\alpha}$. Because our model is best suited for a pre-industrial economy, this production function may also include a fixed stock of land, which has been normalized to one. The return on savings is thus set to zero. An earlier version of the paper included an exogenous, positive return to savings, and the results were qualitatively identical.

Time spent on religion imposes an economic cost by reducing the time that may be spent on labor. The function $\tau(R_{i,t})$ represents agents' perceived beliefs about how religion affects the probability of eternal damnation. I assume that $\tau(0) = -1$ (certain hell), $\tau'(0) = \infty$, and $\tau(1) = 0$ (certain heaven). The parameter σ is the inverse of the intertemporal elasticity of substitution. Agents' discount factors are heterogeneous. Section 3 develops the genetic learning algorithm that determines their evolution.

For any $\beta_{i,t}$, optimization yields the following two first order conditions:

$$C_{i,t}^{-\sigma} = \beta_{i,t}C_{i,t+1}^{-\sigma} \tag{5}$$

$$\alpha N_{i,t}^{\alpha-1} C_{i,t}^{-\sigma} = \tau^{'}(R_{i,t}) \frac{\kappa \Omega \beta_{i,t}^2}{1-\beta_{i,t}} \tag{6}$$

Equations (2)-(6) fully characterize the equilibrium for a given discount factor. Equation (5) is a standard Euler Equation. Equation (6) equates the marginal benefit of an extra unit of labor through increased consumption to the marginal benefit of an increased unit of religion through a lower expected disutility of going to hell.

3 Selection and the Genetic Learning Algorithm

There are two primary explanations for what determines human patience: genetics and socialization. The evidence from evolutionary biology for a genetic basis for human patience is persuasive.[7] Rosati, et. al. [2007] find evidence that the capacity for patience evolved prior to the divergence of human and ape evolution. MacLean, *et al.* (2014) suggest that self-control, closely related to patience, co-evolved along with brain size and that this process was likely driven by dietary factors. Kim, *et al.* [2009] find evidence that time discounting is related to activity in the prefrontal cortex part of the brain in primates, suggesting a biological basis.

The socialization literature instead treats preference traits such as patience as a cultural factor that may be passed down from parents to children. Bison and Verdier [2010] provide an overview and demonstrate that if parents evaluate their childrens' choices using their own preferences (known as "imperfect empathy") then they may choose to invest in passing on their preferences, and distinct sub-populations displaying minority preferences may persist indefinitely. Although the present paper chooses to take the genetic approach, our model could be applied to this framework as well. It would be especially interesting to see if cultural transmissions could allow two distinct levels of patience, and thus religiosity, to co-exist indefinitely.

This paper assumes that agents' discount factors are genetically determined. Other economics papers also assume that natural selection is the the most sensible basis for preference parameters in the long run [Rogers 1994, Becker 1976, Hirshleifer 1977, Coase 1978, and Hansson and Stuart 1990]. The genetic algorithm follows Arifovic, Bullard, and Duffy [1997].[8] At the end of each period, reproduction occurs. For simplicity, I treat reproduction as exogenous; agents obtain no utility from successfully having children.[9] I thus assume that a genetic learning algorithm determines $\beta_{i,t}$, and selection occurs based on W_{t+1}. Critically, the genetic algorithm does not directly select on religion.

The population consists of Z households. Each household's discount factor is determined by a X digit binary string, denoted Q_i. For example, $Q_i = [0, 1, 0, 0, 1, ...1]$. I use the following process to determine agents' discount factors:

$$\beta_{i,t} = \left(0.001 + Q_i * \begin{bmatrix} 2^{X-1} \\ 2^{X-2} \\ . \\ . \\ 4 \\ 2 \\ 1 \end{bmatrix} \right) (0.002 + 2^X - 1)^{-1} \tag{7}$$

Including 0.001 and 0.002 in (7) ensures that the discount factor is bounded between zero and one. The maximum discount factor, just below one, occurs in conjunction with a string of X ones. A string of X zeros results in a discount factor just above zero. Natural selection occurs through a three step process:

1. Reproduction

$2Z$ pairs of strings are drawn at random, with replacement. The measure of genetic fitness is wealth, W_{t+1}. One motivation for this assumption comes from studies on infant mortality. These find that both education and wealth, which are highly correlated, reduce infant mortality.[10] Although I focus on wealth, I expect that if education were added to the model, then as long as patient households tend to also choose higher levels of education, then the model's main mechanism would be very similar. Another motivation comes from Malthusian economics. Ashraf and Galor [2011], for example, find evidence that in pre-industrial societies, increases in wealth were passed through to a larger population so that per-capita incomes stagnated.

The string with the higher value of W_{t+1} is selected and replicates by entering the population for period $t + 1$. I also consider a case where the string with the higher value of W_{t+1} instead may be selected with probability greater than one-half, but less than one. The only impact of this change is to reduce the rate of convergence.

2. Mutation

I define the probability of mutation as $p^m > 0$. For each digit in each string, a random number is drawn from a uniform distribution between zero and one. If this number is less than p^m, then the digit mutates by changing from zero to one or vice-versa. If the random number is greater than p^m, then the digit is unchanged.

3. Crossover

Crossover is another genetic operator. The strings, having been subjected to mutation, are next randomly grouped into $\frac{Z}{2}$ pairs. For each pair, crossover occurs with probability $p^c > 0$. If crossover occurs, an integer, F, is drawn from a discrete uniform distribution between 1 and $X-1$. The first F digits of string 1 are then combined with the last $X-F$ digits of string 2. The first F digits of string 2 are also combined with the last $X-F$ digits of string 1. Crossover thus yields two new strings.

4 Simulations

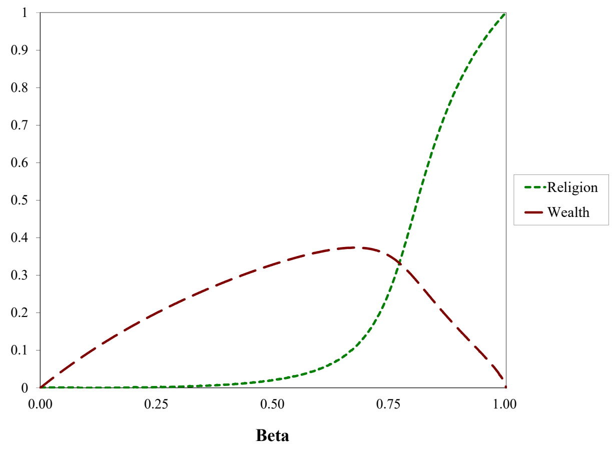
To simulate the model, I specify the following functional form for $\tau(R_{i,t})$:

$$\tau(R_{i,t}) = \frac{ln(R_t)}{1 - ln(R_t)} \tag{8}$$

Following Arifovic, Bullard, and Duffy [1997], and Grefenstette [1986], I set $p^m = 0.0022$ and $p^c = 0.95$, common calibrations in the literature. The model converges to the neighborhood of a steady state discount factor as long as p^m is not too large. Around this steady state, mutation and crossover combine to create some volatility. I assume that utility is logarithmic in consumption by setting $\sigma = 1$, alternate calibrations have no noticeable effect on the results. Calibrating the disutility of hell is challenging, although it seems like it should be high. I set $\kappa\Omega = 1$ and discuss the effects of changing $\kappa\Omega$ later in this section. Finally, I set $X = 10$, and $Z = 1000$. These two values are large enough so that, once convergence has occurred, aggregate volatility is low.

I have deliberately chosen a model where there is no interaction among households. As a result, the model's control variables depend only on each household's discount factor. Figure 1 plots religion and wealth as a function of $\beta_{i,t}$ for this parameterization. Very high discount factors cause agents to spend most of their time on religion, allowing for low labor supply and wealth accumulation. Very low discount factors lead to low savings rates and wealth. An intermediate discount factor, $\beta_{i,t} = 0.69$, maximizes wealth.

Figure 1: Wealth and Religion as a Function of β

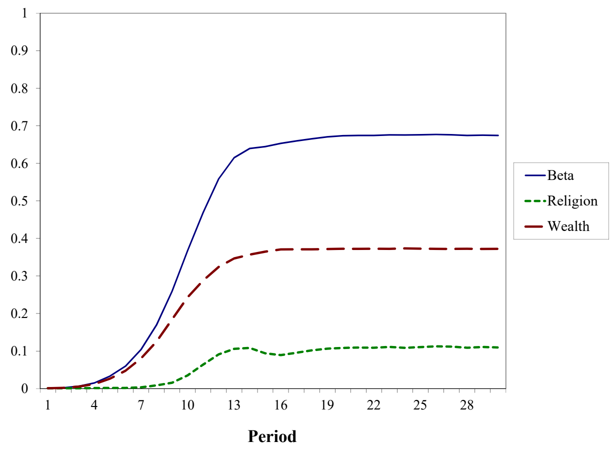


I now conduct a series of simulations to demonstrate the model's behavior. Because the genetic algorithm is random, so is the exact path of each simulation. All simulations were conducted repeatedly, however, and the results were always very similar.

Simulation #1

I first set all agents' initial discount factors close to zero. As seen in Figure 1, this initial condition results in minimal wealth accumulation and thus poor genetic fitness. Figure 2 demonstrates a typical simulation:

Figure 2: Convergence from Low Initial Average Discount Factor ($\kappa\Omega = 1$)



At the initial conditions, the average agent is very impatient. She thus chooses very little savings, which harms his both her wealth at the end of period t, and her reproductive fitness. Because she is impatient, she does not care much about the afterlife and therefore chooses a low level of religion. The genetic algorithm then selects agents with higher discount factors who accumulate more wealth. As a side effect, the agent becomes more religious. More religion reduces fitness, all else equal, but this effect is trumped by the effect of an increased savings rate.

The exact process of convergence is random. In general, the speed of convergence depends on several factors. Higher mutation and crossover rates cause the model to converge faster. Likewise, if the initial conditions include more heterogeneity than in this simulation, then the genetic operators are more efficient and convergence occurs more rapidly.

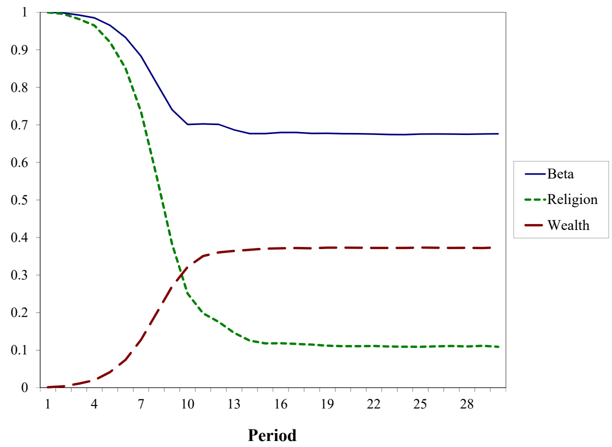
There is thus a genetic source for religion. If looked at atheoretically, Figure 2 could mistakenly suggest that the genetic algorithm does select based on religion. In this model, however, there is no God Gene. The genetic algorithm determines only an economic factor, the discount factor, and increased religiosity is a side effect. Restricting religion to a lower level would increase evolutionary fitness (while reducing expected utility). Nevertheless, religion persists in the long-run.

Figure 2 also demonstrates a secondary result of interest. Religion begins near zero, but then increases above its eventual value before finally converging. Near the initial conditions, almost all agents have very low discount factors and poor fitness. Some mutations result in very high discount factors and religion, and these may be selected early in the process. Until the genetic operators are able to eliminate these strings, they skew the average level of religion above its long run value. This "hump shaped" process of convergence is typical for this simulation.

Simulation #2

I now repeat the previous simulation with different initial conditions which impose the maximum discount factor for all agents (by setting all digits in all strings equal to one). All variables still converge to the same steady state as in Simulation #1. At these initial conditions, agents are exceptionally patient and they thus care a great deal about the afterlife. They choose a high level of religion which reduces their labor and wealth. Their genetic fitness is poor and the genetic algorithm then selects agents with lower discount factors who supply more labor and accumulate more wealth. Figure 3 shows the results:

Figure 3: Convergence from High Initial Average Discount Factor ($\kappa\Omega = 1$)



The question that this paper attempts to answer may also be reversed: why have agents not evolved discount factors arbitrarily close to one when doing so would increase their genetic fitness?[11] Simulation #2 provides an explanation. Ultra-patient agents are be overly concerned about the afterlife and thus choose an excessively high amount of religion.

Simulation #3

So far, the analysis has set $\kappa\Omega = 1$. This compound parameter may be interpreted as the fervor of religious beliefs, encompassing both the certitude of believers and the consequences of apostasy. This simulation is identical to Simulation #1 except that it considers the alternate parameterizations $\kappa\Omega = 10$ and $\kappa\Omega = 0.1$. Figures 4 and 5 report the results.

Figure 4: Convergence from Low Initial Average Discount Factor ($\kappa\Omega = 10$)

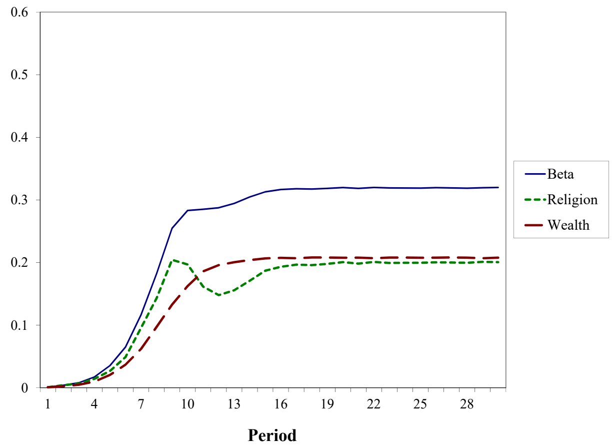
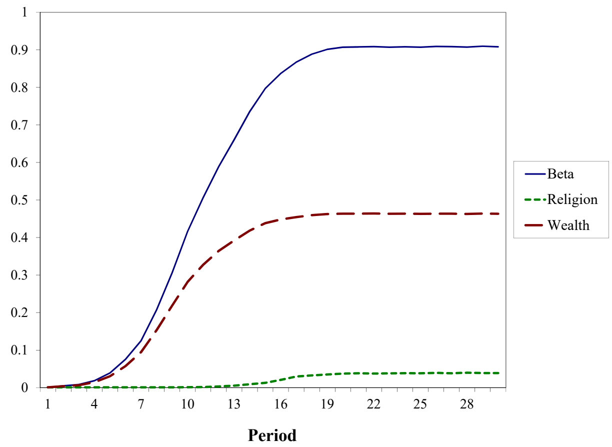


Figure 5: Convergence from Low Initial Average Discount Factor ($\kappa\Omega = 0.1$)



All else equal, a higher value of $\kappa\Omega$ results in more religion and less wealth. To prevent too many resources from being devoted to religion, the genetic algorithm selects agents with lower discount factors. Although lower discount factors reduce the savings rate, the larger effect on wealth comes from a lower value of religion.

Simulation #3 suggests that more religious societies are poorer and more impatient than less religious societies. This simulation compares alternate values of $\kappa\Omega$, although flatter values of $\tau^{'}(R_{i,t})$, agents' belief about how more time on religion affects the chances of hell, also yield more wealth and patience. I emphasize that this result does not connect welfare and religion. In the model, all agents are fully optimizing conditional on their beliefs about the afterlife. Any policy that imposes an alternate value of religion is thus welfare reducing.

This prediction could be applied to some of the world's existing religions. The Catholic hell depicted in Dante's Inferno, for example, appears to provide more disutiliy than the Buddhist belief that a bad life will lead to a less pleasant reincarnation. The model predicts that the Catholic view leads to less wealth and a lower discount factor. The model may also be used to analyze the long-standing Christian debate between the merits of faith vs. good works as a means to salvation. More reliance on good works (assuming these do not increase production) may be interpreted as a steeper value of $\tau^{'}(R_{i,t})$, also leading to less wealth and patience.

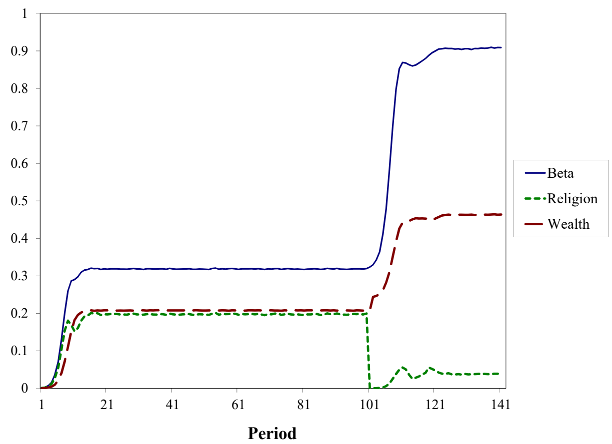
The empirical evidence on the connections among religiosity, patience, and wealth is limited and mixed. A few growth papers consider religion. Barro and McCleary [2003] write that "empirical research on the determinants of economic growth typically neglects the influence of religion." Their paper finds that belief in heaven and hell increases growth but that church attendance reduces growth. Guiso, Sapienza, and Zingales [2003] find that religious intensity is positively correlated with attitudes that are favorable for growth. Using microeconomic data on church membership, Azzi and Ehrenberg [1975] find that religiosity is generally increasing with statewide income, but decreasing with household income.

Very little work connects patience to religiosity. One example is Weatherly and Plumm [2012], who find that patient people tend to posses more intrinsic religiosity, defined as religious activity motivated by one's beliefs rather than for example, a desire to gain social status. They also find that patient people are less likely to be religious fundamentalists. More work connects patience and increased wealth. Galor and Özak [2016] find that regions with higher agricultural productivity in the pre-industrial era display persistently higher discount factors. The genetic algorithm of this paper, by design, yields a similar result. Hubner and Vannoorenberghe [2015], and Strulik [2012] find that patience leads to higher levels of wealth. In this paper, such a relationship exists among societies which have converged to their steady state discount factors, although pre-convergence, too much patience leads to reduced wealth.

Simulation #4

We now consider the case of a "Reformation" where a religion become less concerned about hell. For the first 100 periods, the religion has a strong belief in the afterlife, $\kappa\Omega = 10$. In period 100, however, this view weakens so that $\kappa\Omega = 0.1$.

Figure 6: Negative Shock to Religious Intensity



When this change occurs, religion falls from its initial steady state to near zero. Agents then start to evolve to become more patient. This causes religion to partially recover, returning to a new, lower steady state. A relaxation of religious views thus leads to an overshooting of religiosity.

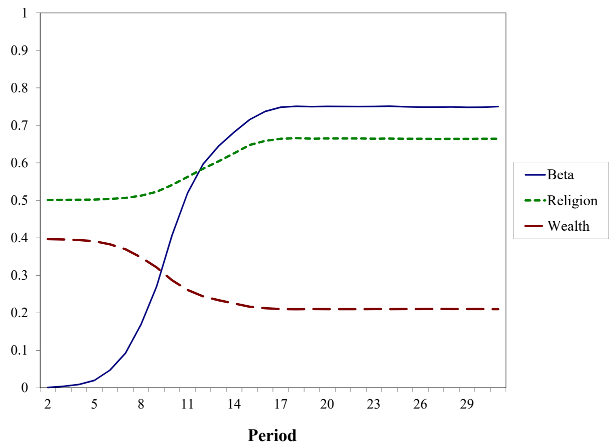
Simulation #5

So far, religion has provided no benefit beyond reducing the risk of hell. As discussed in the Introduction, however, there is an extensive literature providing alternate economic rationals for religious activity. To illustrate that this model is compatible with these other explanations, I now modify the production function so that religion boosts productivity:

$$Y_{i,t+1} = (R_{i,t}N_{i,t})^{\alpha} \tag{9}$$

Religion now provides an economic benefit by acting as a compliment to labor in the production function. Absent any other motivation to spend time on religion, agents now set $N_{i,t} = R_{i,t} = \frac{1}{2}$. This is the floor on their religiosity and the other factors discussed in this paper now cause religion to rise above $\frac{1}{2}$, instead of rising above zero as in the first four simulations. Otherwise, the model's behavior is the same. Figure 7 repeats Simulation #1 with religion in the production function.

Figure 7: Convergence with Religion in the Utility Function



Initially, agents are highly impatient and they thus choose to spend about half of their time on religion. As the genetic algorithm selects more patient agents who accumulate more wealth, however, religion rises above one-half in order to offset concerns about eternal damnation. The steady state level of religion is notably much higher than in Figure 2, where religion does not boost productivity.

5 Conclusions and Extensions

I conclude by discussing several limitations and possible extensions of the model. First, throughout the paper, I assume that religious beliefs ($\kappa\Omega$ and $\tau(R_{i,t})$) are exogenous. Were the genetic algorithm to also determine $\kappa\Omega$, then it would select values close to zero and agents would choose very little religion. I argue that this paper's approach is reasonable. Although natural selection surely influences belief formation, it likely determines the process of expectations formation, rather than a specific belief. $\kappa\Omega$ is thus best interpreted as some type of boundedly rational expectation of the likelihood and nature of an afterlife.

Nevertheless, it would be interesting in future work to model the supply side of religion by endogenizing religious beliefs. It is of particular interest to see what conditions are needed to allow multiple religious modes to co-exist over long horizons.

Another limitation is the assumption that fertility is exogenous. It is clear that many religions command their followers to reproduce. The advent of family planning has enabled agents to better choose their number of offspring. At least in modern times, more religious agents may therefore enjoy an added evolutionary advantage over less religious agents. This premise may be added to the model by assuming that fitness depends on both wealth and religion. With these two modifications, the level of religion that maximizes fitness will now generally be higher than in this paper, but less than one: an agent who spends 100% of their resources on religion will still exhibit poor fitness. In such a model, the mechanism of this paper would still exist. Agents will continue to choose a level of religion above the value (no longer zero) that maximizes fitness. In equilibrium, decreasing religion (locally) will continue, all else equal, to improve evolutionary fitness.

It is difficult to reconcile the apparent economic costs of religion with an evolutionary process that also selects a high level of religion. Many efforts attempt to identify less obvious economic benefits of religion that dominate the more obvious costs. This paper does not argue that this approach is invalid. Instead, it attempts to explain relatively high levels of religion in an environment where religion is costly and selection depends only on economic factors. The genetic learning algorithm encounters a tradeoff. If the initial average discount factor is too high, then the genetic algorithm will choose lower discount factors that result in less religion despite a lower savings rate. If the initial average discount factor is too low, however, then the genetic algorithm will select higher discount factors. What appears to be selection on religion is actually a side effect of selection based on only economic factors. Religion thus exists in equilibrium despite the fact that, all else equal, it reduces reproductive fitness.

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Notes

[1]Berman and Iannaccone [2006] provide an example of economists arguing in support of the reasonableness of Pascal's Wager.

[2]Cavalcanti, Parente, and Zhao [2007] is the only other paper that I am aware of to explicitly include the disutility of hell in a growth model. In their paper, Catholics and Protestants have different beliefs about how work affects the probability of salvation. The disutility of hell is exogenous and does not depend on the discount factor. Azzi and Ehrenberg (1975) include the utility from an afterlife in a microeconomic setting.

[3]See Hamer, D. 2005. "The God Gene : How Faith is Hardwired into Our Genes." *Doubleday Press.* Hamer also reported to have found a single gene responsible for much of variation in religiosity, but he has since backed off of this claim.

[4]*Time Magazine*, 10/25/04.

[5]See Wade, N. 11/14/09, "The Evolution of the God Gene." *The New York Times.* The plausibility of group selection under evolution remains controversial.

[6]The model may also include a labor-religion allocation problem in the second period of life. As long as the opportunity to be religious in the second period does not completely eliminate the incentive to be religious in the first period (*e.g.* a deathbed conversion ensures entrance to heaven), the paper's mechanism and conclusions are unaffected.

[7]Santos and Samuelson [2015] provide a useful general overview between evolutionary biology and economic decision making.

[8]For further discussion of genetic algorithms and other examples of their use in macroeconomics, see Arifovic [2000], and Arifovic and Gencay [2000].

[9]An alternate, more complex, approach is to assume that agents also choose how much time to devote to fertility, child rearing, courtship, etc. More time increases the probability of having children who provide utility. In this case, time dedicated to religion reduces the time available for reproductive activities and the paper's main mechanism is again present. Additionally, if children provide utility only later in life, then the model includes an additional mechanism where selection favors higher discount factors.

[10]For a summary, see Fuchs, Pamuk, and Lutz [2010].

[11]One sensible reason for discount factors less than one is the possibility of death. Because

this uncertainty is suppressed in the model, the equilibrium value of $\beta_{i,t}$ should be interpreted as the discount factor independent of the probability of death.