

## Religion and Substance Abuse

SANGHO YOON\*  
Department of Economics  
George Mason University  
4400 University Dr. 3G4  
Fairfax, VA 22030

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### ABSTRACT:

Recent efforts by economists have shown some success in researching religion-related behaviors in individual, group, and cultural level. How religion may affect substance use is an area where such efforts have been relatively at minimal, while the literature in sociology, psychology, and medicine has recognized a general stylized fact of the negative relationship between religion and substance use. This paper identifies the economic explanation that links religion and substance use by employing the rational addiction framework initially developed by (Iannaccone 1984, 1986) and Becker and Murphy (1988). We construct a dynamic model where an individual consume two commodities that accumulate consumption capitals. We expect three religious effects to reduce substance use. First, as the consumption capital from substance use is dissipated by religious practice, current substance use is much less enforced from past use. Second, as the satisfaction gap between a given level of substance use in past and today becomes narrower, higher level of past substance use leads to much less loss in the utility from current substance use. And third, the reduction or interruption in current substance use does not result in the reduction in utility. As the increase in religious practice causes three effects, an individual chooses to reduce substance use.

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\* Ph.D. Candidate. Email: [syoon@gmu.edu](mailto:syoon@gmu.edu) Phone: (703) 993-1141 Fax: (703) 993-1133  
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SangHo Yoon

George Mason University

“And take heed to yourselves, lest at any time your hearts be overcharged with surfeiting, and drunkenness, and cares of this life, and so that day come upon you unawares.”

Exodus 20:3; Luke 21:34. Bible, James King Version

### I. INTRODUCTION

Despite of many predictions based upon the secularization theory that religion is “doomed to disappear in an era of science and general enlightenment” (Lenski 1961), there is a clear sign that religion remains as a significant part of American’s life. For instance, (Hadden 1987), by using the Gallop’s annual *Religion in America* report for 1985, reports that church membership and church attendance in America have been stable since 1940s, and (Stark and Bainbridge 1985) argue that two counterbalancing forces of religion – “revival” and “religious innovation” – will enable “the amount of religion” in societies to “remain relatively constant”. Thus, it is not surprising to see that economists recently have recognized the importance of religion and begun to study behavioral and organizational properties of religion.

Unlike economics’ lag in studying religion, its counterpart in sociology has continuously produced research programs that are exclusively devoted onto studying various aspects of religion at individual, social, and cultural level. However, sociology of religion, while abundant in documenting empirical patterns in religions, lacks the theory, and much progress of understanding religion awaits the combined effort of economic theory and sociology data (Iannaccone 1998). One such area is the religious effect on substance use or abuse. While the empirical literature examining the link between two has produced more than 200 papers in sociology, psychology, and medicine, why two may actually link each other relies on only three theoretical frameworks – hellfire, social bonding, and this-worldly sanction hypotheses.

In this paper, we propose an economic theory that explains the link between religion and substance use, and provide the model analysis to show the religious effect on substance use. In economics, both religion and substance use are regarded to be the consumption of addictive commodities, and only difference is whether beneficial or harmful, respectively (Becker and Murphy 1988). Under the economic definition of rational addiction that “its current consumption increases” as the stock of consumption capital” derived from its previous consumption accumulates” (Iannaccone 1986) and that “the positive effect of an increase in” the stock of consumption capital “exceeds the negative effect of such an increase on the future” by increased current consumption (Becker, et al. 1991), religion and substance use belong to the category.<sup>1</sup> That is, religion and substance use are types of the increased consumption behavior that is induced by past experience even with the rise in future price paid.<sup>2</sup>

We investigate the effect of religion on substance use as religious practice accelerates the depreciation of the capital formed by substance use. We begin by developing a general model of habit formation (consumption capital accumulation) where an individual consumes two addictive

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<sup>1</sup> With the provided definition of rational addiction, an individual is *rationally* addicted if one considers the past as well as the future consequences for current consumption decision.

<sup>2</sup> Tolerance, reinforcement, and withdrawal are identified as the main drivers of addiction. For detail discussion of each notion, please see (Chaloupka 1991).

commodities. Unlike usual habit formation model, consumption capitals are not assumed to be *commodity-specific* – that is, a consumption capital is not accumulated by the consumption of a commodity. When the consumption of two commodities influences same consumption capital, two commodities (i.e., religion and substance use) are linked dynamically.<sup>3</sup>

When an individual's religious practice increases, we expect to see three effects: First, as the consumption capital from substance use is dissipated by religious practice, current substance use is much less enforced from past use. Second, as the satisfaction gap between a given level of substance use in past and today becomes narrower, higher level of past substance use leads to much less loss in the utility from current substance use. And third, the reduction or interruption in current substance use does not result in the reduction in utility. As the increase in religious practice causes three effects, an individual chooses to reduce substance use.<sup>4</sup> Moreover, these effects are closely related to three hypotheses that are used in the empirical testing concerning the link between religion and substance use.

The paper proceeds in following manner: In section II, we review the empirical literature on religion and substance use based on three benchmarks for data analyses. The literature review brings our attention to the stylized fact of the negative association between religion and substance use. In section III, we develop and present the model of two addictive commodities. The first order conditions are presented, while other canonical and transversality conditions are specified. The interpretation of the first order conditions show how religion and substance use can be treated as addictive commodity. It also confirms the results identified in previous rational addiction papers.

## II. LITERATURE REVIEW AND STYLED FACT

This section provides the overview of previous findings on religion and substance use. In the literature, whether religion and substance use is negatively related or have any association is statistically tested based upon three hypotheses – hellfire, reference group, and moral community hypotheses.<sup>5</sup> Empirical support for each hypothesis somewhat differs. However, there seems to be a consensus converging onto a stylized fact, the negative association between religion and substance use.

***Hellfire Hypothesis*** – The systemic examination of religion and substance use began with the paper by (Hirschi and Stark 1969) that disputed the existence of the relationship between religion and delinquency. Although substance use was not a part of delinquency they examined, one of their postulated links between religion and delinquency that failed to be confirmed by their data analysis provided the framework that led many subsequent works on religion and substance use

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<sup>3</sup> Readers should note the difference in our treatment for *non-commodity-specific* consumption capital. When the assumption of *commodity-specific* consumption capital is relaxed, it automatically leads to the consumption of a commodity being responsible for the accumulation of two capitals. However, we pinpoint the key feature of *non-commodity-specific* consumption capital to be a capital being accumulated and/or dissipated by the consumption of different commodities. See Appendix C in (Becker and Murphy 1988) and model in (Dockner and Feichtinger 1993) for the usual set-up of *non-commodity-specific* consumption capital models.

<sup>4</sup> The direction of causality may also be in a reversal order. We expect same effects will take place on religious practice when an individual increases substance use, indicating the bi-causality between religion and substance use.

<sup>5</sup> For more complete review of literature, please see (Chadwick and Top 1993; Cochran and Akers 1989; Koenig, et al. 2001; Miller 1998).

(Bock, et al. 1987; Chadwick and Top 1993; Cochran and Akers 1989; Stark 1996). The hellfire hypothesis they suggested is that, as people believe in punishments in hell for wrongdoings while on earth, they are deterred from delinquency including substance use.<sup>6</sup>

Ironically the hellfire hypothesis, we believe, can be explained most clearly by the “salvation motive” identified by the model in (Azzi and Ehrenberg 1975), which is claimed to be the first work in the economics of religion since Adam Smith (Iannaccone 1998). In the model of the “salvation motive”, they posit that a household rationally devotes their time and effort in religious activities for the expected afterlife consumption – that is, the expected afterlife benefit is the factor that influence today’s choice of a household among secular and religious activities. Inversely an individual can believe that delinquent behaviors including substance use lead to the punishment in hell (or the negative consequence in the expected afterlife benefit). Then this individual’s choice is obvious; *don’t do something that will direct you to the hell*.

While the empirical support of the hellfire hypothesis has not been so positive for religion and delinquent behaviors (Burkett and White 1974; Hirschi and Stark 1969), almost every study that applies the hellfire hypothesis exclusively to religion and substance use has confirmed the existence of the negative association between two. For example, (Adlaf and Smart 1985; Hardert and Dowd 1994) find that religion deters illicit drug use more than licit one, and (Cook, et al. 1997) find that religion equally deters both. However, including the study of (Elifson, et al. 1983) which finds that religion is much more influential on victimless crime like smoking marijuana and drinking alcohol, many have argued for the antiasceticism hypothesis that the effect of religion is particularly (or only) strong on substance use as religion is one of very few institutions that prohibit such uses but the society overall allows (Albrecht, et al. 1977; Burkett and White 1974; Cochran and Akers 1989; Dudley, et al. 1987; Elifson, et al. 1983; Hadaway, et al. 1984; Khavari and Harmon 1982; Mason and Windle 2002). Thus, although opinions on the religious effect on legal or illegal substance use differ in the literature, a consistent view at least on religion and substance use exists: There is a negative relationship between religion and substance use.

***Reference Group Hypothesis*** – While the hellfire hypothesis leading to a simple bivariate association has been supported by many empirical findings, the relative strength of the relationship is subject to other contextual factors. One of contextual factors that have gotten the attention is how the religious group an individual belongs to affects the relationship between religion and substance use even as the group’s norm is used as the behavioral reference (Cochran and Akers 1989). For example, the Catholic Church has a much more liberal attitude toward substance use than the fundamental Protestant Church which may not even allow alcohol use for liturgical purpose (Cochran, et al. 1992). Then, how religion and substance use relate each other would be influenced by the group characteristic on substance use and how strongly a believer is attached to the religious group. Thus, it can be conjectured that the more proscriptive a religious group that an individual belongs to the more likely an individual abstain from substance use.

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<sup>6</sup> Recently (Harris 2003) postulated that the belief in “earthly rewards and punishments” from God may be more important and significant deterrent effect of religion on substance use. Using adolescent data from the Mormon Church that promotes the idea of this-worldly sanction by God, he argued that the belief in earthly sanction has a relatively larger deterrent effect on future substance use than one in the hellfire. However, his argument rests on same logic that the belief in sanction deters delinquent behaviors. Only difference is whether an individual believe in sanctions in afterlife or during the lifetime shorting after the wrongdoings.

Such a framework, known as the reference group hypothesis, led to a volume of studies that examine the relative effect of religion on substance use (mainly alcohol and marijuana use). For example, Cochran and his associates, using data from the General Social Surveys, continuously have found that the effect of religion on alcohol use varies by the denomination's degree of proscriptiveness and that individuals in the proscriptive denominations are less likely consume alcohol (Beeghley, et al. 1990; Bock, et al. 1987; Clarke, et al. 1990; Cochran, et al. 1988, 1992). Their conclusion has been confirmed by other works in medicine and psychology as well, and the use of specific denominational effect on substance use have been pointed as a potential method to treat substance abuser (Ahmed, et al. 1994; Alexander and Duff 1991; Carlucci, et al. 1993; Koenig, et al. 1994; Patock-Peckham, et al. 1998).

Several studies, however, have argued for the nonsignificance of denominational context in the relationship between religion and substance use (Amoateng and Bahr 1986; McIntosh, et al. 1981). (McIntosh, et al. 1981) claim that the religious effect leading to less drug use is universal and consistent regardless of people's denominational association. Moreover, Jews who, according to Cochran and associates, belong to the nonproscriptive denomination are often found much less likely to be substance abuser (Carlucci, et al. 1993; Glassner and Berg 1980). However, the mixed results over the reference group hypothesis do not dispute the negative relationship between religion and substance use. It is only whether the denominational context has any effect in the strength in such a relationship.

***Moral Community Hypothesis*** – As stated above, the first application of the hellfire hypothesis to religion and general delinquent behavior by (Hirschi and Stark 1969) fails to be confirmed. In contrast to the antiasceticism hypothesis, (Higgins and Albrecht 1977) suggest that the failure of (Higgins and Albrecht 1977) is from the selection bias of using data of nonreligious northern California. After finding negative correlations between religion and 17 types of delinquent behavior using data of religious South (Atlanta, Georgia), they argue that religion is perceived differently depending on the community's religious characteristic. Thus, similar to the reference group hypothesis, the group's contextual effect – that is, the religiosity of surrounding secular communities – was called to be in operation. In sum, the moral community hypothesis states that the deterrent effect of religion requires the support of the community and becomes only significant when it is ratified the social environment (Cochran and Akers 1989; Stark 1996).

This has produced subsequent papers that examine aggregate religiosity in the community and substance use, and has been confirmed by (Amey, et al. 1996; Richard, et al. 2000; Tittle and Welch 1983; Welch, et al. 1991). Moreover, the moral community hypothesis has even triggered one of coauthors, Rodney Stark, who claimed the nonexistence of religious effect on delinquency to change the opinion (Stark 1996; Stark, et al. 1982).<sup>7</sup> One exception seems to be the study conducted by (Chadwick and Top 1993) where they report that the community's religious climate does not make any difference on the religious effect on adolescent delinquency (including substance use) but that religion reduces delinquency regardless of community's religiosity.

Based the finding that the religious effect on substance use is reduced when some other contextual factors such as peer association, parental religiosity, and other family characteristics are controlled for, some have argued that the religious effect on substance use is indirect and religion is rather used as a selection mechanism that diminishes the chance to be exposed to

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<sup>7</sup> (Stark 1996) note why and how his thought on religion and delinquency has changed and developed over the course of time.

substance use (Bowker 1974; Burkett and Warren 1987; Foshee and Hollinger 1996; Kandel, et al. 1976; Perkins 1987). Such an argument does not necessarily question the validity of the negative association between aggregate religiosity and substance use. It, however, challenges the causality of the moral community hypothesis. That is, the negative association between aggregate religiosity and substance use can be actually the result of a highly religious individual choosing to live in highly religious community. Thus, although how the community's religiosity controls or interacts with individual religiosity is debatable, the negative relationship between religion and substance use is clearly supported.

As our literature review suggests, the level of the empirical support on each hypothesis differs. However, there is a consensus view on how religion and substance use are related. A stylized fact of the negative association between religion and substance use are numerous suggested by existing findings. We now turn to our model to show how and why such a link between religion and substance use exists in economic point of view.

### III. THE MODEL

This section develops the dynamic model of two addictive commodities. While the sociology of religion has identified a stylized fact of the negative relationship between religion and substance use, how and why such a relationship is established are not still clear. The purpose of the model is to systematically examine the link between religion and substance use.

We adopt a general 'habit formation' model as in (Iannaccone 1984, 1986) and (Becker and Murphy 1988), and consider the utility of a rational individual at any moment of time that depends on the consumption level of two addictive commodities,  $c_1$  and  $c_2$  – religion and substance use, respectively. As both commodities are assumed to be time-dependent, current utility not only depends on the level of current consumption but also on the measure of past consumptions. Then the utility function can be written as in

$$U(t) = u[c_1(t), c_2(t), S_1(t), S_2(t)]. \quad (1)$$

Equation (1) is assumed to be twice differentiable, concave jointly in  $[c_1, c_2, S_1, S_2]$ , and strictly concave and increasing in  $c_1$  and  $c_2$ .  $S_1$  and  $S_2$  are the stock of consumption capital. On the other,  $[S_1, S_2]$  characterizes the effect of cumulative past consumption on current utility.

Two symmetric investment functions characterize how the stocks of consumption capitals are accumulated:

$$\dot{S}_1 = c_1 + \phi_2 c_2 - \delta_1 S_1(t) \quad (2)$$

and

$$\dot{S}_2 = c_2 + \phi_1 c_1 - \delta_2 S_2(t). \quad (3)$$

$\dot{S}_i$  are the rates of change over time in  $S_i$ , and  $\delta_i$  are the depreciation rates of consumption capitals. We assume that the depreciation rate is stable and same over time,  $\delta_i(t) = \delta_i$ . Equations (2) and (3) are subject to boundary conditions of

$$S_i(0) = S_{0i} \text{ and } S_i(T) \geq 0. \quad (4)$$

As equations (2) and (3) indicate, the accumulation of a capital is assumed not to depend solely on one commodity but also on the other.<sup>8</sup> That is to say, consumption capital is assumed to be *non-commodity-specific*. We also include a coefficient  $\phi_i$  in the investment functions. This is to allow the variation or difference on the effect of two commodities on the accumulation process. However, a particular capital is assumed not to have any role in the accumulation of the other capital. This can be justified as the depreciated level of a consumption capital ( $\delta_i S_i$ ) and current consumption of the other commodity ( $c_{j \neq i}$ ) already endogenously reflect the effect of the other capital  $S_{j \neq i}$  in the accumulation process.

An individual also faces the expenditure constraint subject to the lifetime wealth. If we assume that the rate of interest,  $r$ , is constant, that capital market is perfect, that the initial wealth endowment is  $A_0$ , and that the income at a time,  $Y(t)$ , depends on the level and characteristic of consumption capital accumulated, then the lifetime budget constraint is characterized by

$$A_0 \geq \int_0^T e^{-rt} (c_1(t) p_{c_1}(t) + c_2(t) p_{c_2}(t) + \delta_1 p_{\delta_1}(t) + \delta_2 p_{\delta_2}(t)) dt - \int_0^T e^{-rt} Y[S_1(t), S_2(t)] dt \quad (5)$$

where  $p_{c_i}$  and  $p_{\delta_i}$  denote the price of commodities and depreciate rates, respectively. Equation (5) is subject to boundary conditions of

$$A(0) = A_0 \text{ and } A(t) \geq 0. \quad (6)$$

which shows the initial and final conditions of wealth accumulation.

With a length of life equal to  $T$  and a constant rate of time preference of  $\rho$ , the dynamic problem of an individual is to find two non-negative piecewise continuous consumption paths,  $c_i(\cdot)$ , simultaneously which maximizes lifetime utility,

$$\max_{c_1(t), c_2(t)} \int_0^T e^{-\rho t} u[c_1(t), c_2(t), S_1(t), S_2(t)] dt \quad (7)$$

subject to (2), (3), and (5) with given boundary conditions of (4) and (6).

By introducing costate variables,  $\lambda_i(t)$  and  $\mu[t]$ , the current-valued Hamiltonian of this problem is simply

$$H = u[c_1, c_2, S_1, S_2] + \lambda_1 (c_1 + \phi_2 c_2 - \delta_1 S_1) + \lambda_2 (\phi_1 c_1 + c_2 - \delta_2 S_2) + \mu \left( -e^{-rt} (c_1 p_{c_1} + c_2 p_{c_2} + \delta_1 p_{\delta_1} + \delta_2 p_{\delta_2}) + e^{-rt} Y[S_1, S_2] \right). \quad (8)$$

[The derivation of the current-value Hamiltonian can be found in Appendix A. and time subscript is suppressed hereafter.]

If the constraint qualification is satisfied, then the maximum principle requires the first order conditions of the Hamiltonian that

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<sup>8</sup> This assumption enables is to explore the interaction between two addictive commodities. Once the consumption capital is assumed to be commodity-specific as in (Iannaccone 1984, 1986) and (Becker and Murphy 1988), the link between addictive commodities is implicitly assumed to be non-existence. It is because, under the definition of commodity-specific capital that there exists a unique or exclusive relation between an addictive commodity and a consumption capital, the Edgeworth-Pareto cardinal indicator among a commodity and the other capital is zero (Dockner and Feichtinger 1993). In consequence the Edgeworth-Pareto cardinal indicator among commodities becomes zero indicating that two commodities are independent (McKenzie 1977).

$$H_{c_1} = u_{c_1} + \lambda_1 + \phi_1 \lambda_2 - \mu p_{c_1} e^{-rt} = 0 \quad (9)$$

and

$$H_{c_2} = U_{c_2} + \phi_2 \lambda_1 + \lambda_2 - \mu p_{c_2} e^{-rt} = 0. \quad (10)$$

And costate equations, which are other necessary conditions, are

$$\dot{\lambda}_1 = -H_{s_1} + \rho \lambda_1 = -u_{s_1} + \lambda_1 (\rho + \delta_1) - \mu Y_{s_1} e^{-rt} \quad (11)$$

and

$$\dot{\lambda}_2 = -H_{s_2} + \rho \lambda_2 = -u_{s_2} + \lambda_2 (\rho + \delta_2) - \mu Y_{s_2} e^{-rt}, \quad (12)$$

while transversality conditions are

$$e^{-\rho t} \lambda_1(T) = 0, \quad e^{-\rho t} \lambda_2(T) = 0, \quad (13)$$

$$\dot{\mu} - \rho \mu = -e^{-\rho t} H_\Gamma = 0 \quad (\text{thus, } e^{-\rho t} \mu \text{ is constant and } \geq 0), \quad (14)$$

$$\Gamma(T) + A_0 \geq 0, \quad \text{and } e^{-\rho t} \mu (\Gamma(T) + A_0) = 0 \quad (15)$$

As in (Iannaccone 1984, 1986), the middle term  $\lambda_i + \phi_i \lambda_{j \neq i}$  in (11) and (12) is the “wedge” that connects the current consumption decision with the future, and expresses the shadow price of the stock accumulation by current consumption.<sup>9</sup> This price system lets a rational consumer to internalize future benefit or cost of consumption capital accumulated by current consumption into the current calculus of the utility. Religious practice, which accumulates beneficial consumption capital, derives the positive wedge ( $\lambda_1 + \phi_1 \lambda_2 > 0$ ), and substance use, which accumulates harmful consumption capital, derives the negative wedge ( $\lambda_2 + \phi_2 \lambda_1 < 0$ ). This leads that religious practice enhances future utility and income level but substance use reduces them. Also it is easy to see that an additional assumption of  $\phi_i = 0$  converts the model into the commodity-specific one where the difference between religious practice and substance use is only dictated only by the sign of  $\lambda_i$ . It also confirms the result of the Becker-Murphy model that, when a commodity is beneficial (harmful),  $u_{s_i} > 0$  and  $Y_{s_i} > 0$  ( $u_{s_i} < 0$  and  $Y_{s_i} < 0$ ).

#### IV. DYNAMICS

The first order conditions (9) and (10) let us extend the economic analysis by defining the familiar optimal condition of the classical consumer theory that the ratio of marginal utility to price for every commodity has to equal each other at a given point of time (Iannaccone 1986). Before any discussion on the properties of the optimal consumption choice between religion and substance use, however, we first need to make some remarks on the condition under which religion and substance use are rationally addictive (adjacent complementarity), which actually has a very close link to the first religious effect we stated in the introduction.

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<sup>9</sup> Interestingly there are two interpretation of the “wedge” in current literature of the rational addiction; one by (Iannaccone 1986) and (Becker and Murphy 1988). (Iannaccone 1986) interprets the “wedge” as “the future utility generated by current consumption,” while (Becker and Murphy 1988) explain it as the part of full price that is the money value of the future cost or benefit of consumption.” That is to say, the wedge can be economically interpreted as a part of the utility of or of the price paid by a rational individual. We follow Iannaccone’s interpretation.

A consumer displays adjacent complementarity “if increasing the consumption of the commodity at some date  $t$  raises the marginal utility from that commodity at nearby dates relative to distant dates”, thus, inducing a rational individual to consume more (Iannaccone 1986). If and only if adjacent complementarity is displayed, current consumption of a commodity increases with an increase in its capitals accumulated from past consumptions.<sup>10</sup> In other words, adjacent complementarity which reflects not only the relation between current and past consumption but also the effect of other variables such as  $\rho$  and  $\delta_i$  is a sufficient condition for rational addiction (Becker and Murphy 1988).

The rational addiction literature examines the connection between adjacent complementary and addiction through looking at two cases exclusively: commodity-specific and non-commodity-specific capital. For example, (Becker and Murphy 1988) show that addiction takes place “if and only if a consumer displays adjacent complementarity” in the case of commodity-specific capital. For the case of non-commodity-specific capitals, while assuming no interaction between consumption capitals, (Dockner and Feichtinger 1993) show that “full addiction” takes place “if and only if his behavior displays adjacent complementarity with respect to both stocks.” Furthermore, they argue that the “partial addiction” of the consumption cycle may occur when a consumer simultaneously “display addictive and satiating behavior” and that “partial addiction” results from adjacent and distance complementarity with respect to two distinct, addictive and satiating, consumption capitals. More specifically they show that the consumption cycle results from the difference in depreciation rates among capitals.<sup>11</sup> However, they do not provide the sufficient condition for rational addiction when two contrasting consumption capitals (from religion and substance use exist). The question is when a consumer will be *even* partially addicted to a commodity when forces from existing consumption capitals work in opposing direction.

To shed light on this question and for the sake of the simplicity, we consider a subset of the model in section III where a rational individual consumes only one commodity that accumulates two consumption capitals. Assuming the price is constant over time ( $\dot{p}_c = 0$ ) and the time preference and interest rate are same ( $\rho = r$ ), and also allowing the linearization of the equations of motion, we derive the characteristic roots given by

$$\beta_{1,2,3,4} = \frac{\rho}{2} \pm \sqrt{\left(\frac{\rho}{2}\right)^2 - \frac{K}{2} \pm \frac{1}{2} \sqrt{K^2 - 4 \det J}} \quad (16)$$

where  $K = M_2 - \rho^2$ . Given the explicit expression of the characteristic roots, we can completely characterize the stability property of the dynamical system where it depends on the sign of terms under two radicals. The first case for the stable roots is when two radicals in (16) are real so that two roots among four are negative. The second case for the stable roots is either when the real components of two complex roots are negative or when two roots have zero real components (i.e. two pure imaginary roots). For both cases we can safely ignore two larger (positive and unstable) roots as they essentially lead to the exponential growth of  $S_i$  and  $\lambda_i$  which violates the transversality condition in (13). [Derivation of (16) and the necessary and sufficient conditions for the stable roots can be found in Appendix B where the subset of the model is also specified.]

<sup>10</sup> Dynamics relates to adjacent and distant complementarity is first developed by Ryder and Heal (1973) and Boyer (1977; 1983).

<sup>11</sup> Becker and Murphy (1988) also provide a similar model with two consumption capitals to explain the binge behavior.

Allowing the transformation such that the steady-state values of  $c$  and  $S_i$  are zero and letting smaller and stable roots be  $\beta_1$  and  $\beta_2$ , the local stable (monotonic or periodic) trajectory is approximated by

$$S_i(t) = e_{11}e^{\beta_1 t} + e_{12}e^{\beta_2 t} \quad (17)$$

and

$$S_j(t) = e_{21}e^{\beta_1 t} + e_{22}e^{\beta_2 t} \quad (18)$$

where  $e_{ij}$  is the element of the eigenvector that solves  $(J - \beta_{1,2}I)e = 0$ . These dynamics suggest that the optimal consumption nearby the stationary point is a linear function of two consumption capitals.

$$C = \alpha_1 S_1 + \alpha_2 S_2 = \frac{(\beta_1 + \delta_1)(\beta_2 + \delta_1)}{(\delta_1 - \delta_2)} S_1 + \frac{(\beta_1 + \delta_2)(\beta_2 + \delta_2)}{(\delta_2 - \delta_1)} S_2 \quad (19)$$

As our definition on addiction suggests, we can define the consumer's behavior as addiction depending on the relationship between the consumption of a commodity and its capitals. In other words, using (20) we can generalize the discussion of addiction by examining the sign and magnitude of coefficients  $\alpha$  and  $\beta$ . Assuming the depreciation rate of a consumption capital is larger than the other,  $\delta_1 > \delta_2$ , coefficients in (20) are positive or negative if and only if  $\text{sgn}(\beta_1 + \delta_1) = \text{sgn}(\beta_2 + \delta_2)$  ( $\text{sgn}(\beta_1 + \delta_1) = -\text{sgn}(\beta_2 + \delta_2)$ ), respectively.

[Dynamics identified above will shed some light on how religion and substance use become addictive. Moreover, we expect that such an insight will let us extend the analysis onto how religion reduce the level of consumption capital of substance.]

## V. RELIGION AND SUBSTANCE USE

[The extension of the dynamic identified in section IV will let us analyze the link between religion and substance use. As stated in Section I, we expect to see three religious effects on substance use.]

## VI. CONCLUSION

[As the analysis of the model developed in section III, it is too early to provide any concluding remarks. Yet, we believe the model will lead to the expected result. There are three religious effects we expect to see. First, as the consumption capital from substance use is dissipated by religious practice, current substance use is much less enforced from past use. Second, as the satisfaction gap between a given level of substance use in past and today becomes narrower, higher level of past substance use leads to much less loss in the utility from current substance use. And third, the reduction or interruption in current substance use does not result in the reduction in utility. Then we will be able to show that, as the increase in religious practice causes three effects, an individual chooses to reduce substance use.]

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## APPENDIX A

**Derivation of equation (8)** – The optimal control problem defined by (7) is a standard isoperimetric problem containing the integral constraint of (4) (Chiang 1992; Hadley and Kemp 1971). To solve this problem, we introduce a new state variable  $\Gamma[\tau]$  into the problem such that (4) is replaced by a condition in terms of  $\Gamma(\tau)$ . Let us define a new constraint condition as in

$$\begin{aligned} \Gamma(\tau) = & -\int_0^t e^{-r\tau} \left( c_1(\tau) p_{c_1}(\tau) + c_2(\tau) p_{c_2}(\tau) + \delta_1 p_{\delta_1}(\tau) + \delta_2 p_{\delta_2}(\tau) \right) d\tau \\ & + \int_0^t e^{-r\tau} Y[S_1(\tau), S_2(\tau)] d\tau \end{aligned} \quad (\text{A1})$$

of which the first derivative with respect to time, the equation of motion for  $\Gamma$ , is

$$\dot{\Gamma} = -e^{-r\tau} \left( c_1(\tau) p_{c_1}(\tau) + c_2(\tau) p_{c_2}(\tau) + \delta_1 p_{\delta_1}(\tau) + \delta_2 p_{\delta_2}(\tau) \right) + e^{-r\tau} Y[S_1(\tau), S_2(\tau)]. \quad (\text{A2})$$

The initial and terminal values, the boundary conditions of

$$\begin{aligned} \Gamma(0) = & -\int_0^0 e^{-r\tau} \left( c_1(\tau) p_{c_1}(\tau) + c_2(\tau) p_{c_2}(\tau) + \delta_1 p_{\delta_1}(\tau) + \delta_2 p_{\delta_2}(\tau) \right) d\tau \\ & + \int_0^0 e^{-r\tau} Y[S_1(\tau), S_2(\tau)] d\tau \\ = & 0 \end{aligned} \quad (\text{A3})$$

and

$$\begin{aligned} \Gamma(T) = & -\int_0^T e^{-r\tau} \left( c_1(\tau) p_{c_1}(\tau) + c_2(\tau) p_{c_2}(\tau) + \delta_1 p_{\delta_1}(\tau) + \delta_2 p_{\delta_2}(\tau) \right) d\tau \\ & + \int_0^T e^{-r\tau} Y[S_1(\tau), S_2(\tau)] d\tau \\ \geq & A_0 \end{aligned} \quad (\text{A4})$$

After introducing this new state variable, the problem of an individual is now to maximize the lifetime utility subject to (2), (3), and (A2) with given boundary conditions of (4) and (A4), and it is easy to see that this leads to equation (8).

## APPENDIX B

**Derivation of (15) and Stability Conditions** – Consider a subset of the general model in section III where only one addictive commodity (either religion or substance use) and two consumption capitals exist. This case is characterized by modifying (7), (2), (3), (A2), (A3), and (A4) as follows:

$$\max_{c(t)} \int_0^T e^{-\rho t} u[c(t), S_1(t), S_2(t)] dt \quad (\text{B1})$$

subject to

$$\dot{S}_1 = c - \delta_1 S_1(t), \quad (\text{B2})$$

$$\dot{S}_2 = c - \delta_2 S_2(t), \quad (\text{B3})$$

and

$$\dot{\Gamma} = -e^{-r\tau} (c(\tau) p_c(\tau) + \delta_1 p_{\delta_1}(\tau) + \delta_2 p_{\delta_2}(\tau)) + e^{-r\tau} Y[S_1(\tau), S_2(\tau)] \quad (\text{B4})$$

with given boundary conditions of (4), (A3) and (A4).

Assuming  $\rho = r$  and as the consumption path is time-differentiable, we may differentiate the modified first order condition from (B1), (B2), (B3) and (B4) with respect to time to obtain

$$\dot{c} = H_{cc}^{-1} U_{cS_1} \dot{S}_1 - H_{cc}^{-1} U_{cS_2} \dot{S}_2 - H_{cc}^{-1} \dot{\lambda}_1 - H_{cc}^{-1} \dot{\lambda}_2 \quad (\text{B5})$$

where  $H_{cc} = u_{cc}$  which is defined to be negative-definite from the concavity of utility in  $c$ .

Linearization of (B2), (B3), (4), (B4), (A3), and (A4) using (B5) yields following system that describes the local stability properties nearby the neighborhood of a stationary point.

$$\dot{X} = J(X^*)(X - X^*) \quad (\text{B6})$$

where  $J(X^*)$  is the Jacobian derivative that is given by

$$\begin{bmatrix} -\delta_1 - H_{cc}^{-1} H_{cS_1} & -H_{cc}^{-1} H_{cS_2} & -H_{cc}^{-1} & -H_{cc}^{-1} \\ -H_{cc}^{-1} H_{cS_1} & -\delta_2 - H_{cc}^{-1} H_{cS_2} & -H_{cc}^{-1} & -H_{cc}^{-1} \\ -H_{S_1 S_1} + H_{S_1 c} H_{cc}^{-1} H_{cS_1} & -H_{S_1 S_2} + H_{S_1 c} H_{cc}^{-1} H_{cS_2} & (\rho + \delta_1) + H_{cc}^{-1} H_{S_1 c} & H_{cc}^{-1} H_{S_1 c} \\ -H_{S_2 S_1} + H_{S_2 c} H_{cc}^{-1} H_{cS_1} & -H_{S_2 S_2} + H_{S_2 c} H_{cc}^{-1} H_{cS_2} & H_{cc}^{-1} H_{S_2 c} & (\rho + \delta_2) + H_{cc}^{-1} H_{S_2 c} \end{bmatrix} \quad (\text{B7})$$

The Jacobian derivative is reduced to a  $4 \times 4$  matrix from a  $6 \times 6$  as the  $\Gamma$  variable is an ‘artifact’ of no direct interest and  $\Delta \mu = 0$  (Chiang 1992). Thus, our characteristic polynomial of (B6) is of degree four as in

$$\det(J - \beta I) = \beta^4 - \text{tr} J \beta^3 + M_2 \beta^2 - M_3 \beta + \det J = 0 \quad (\text{B8})$$

where  $M_2$  and  $M_3$  are the sum of all diagonal second and third order minors of  $J$ , respectively.

Using the elements in the Jacobian derivative as in (B7), we can specify the coefficients of (B8) and their relations.

$$\text{tr} J = 2\rho \quad \text{and} \quad \frac{(-\text{tr} J)^3}{8} - \frac{-\text{tr} J \times M_2}{2} - M_3 = -\rho^3 + \rho M_2 - M_3 = 0$$

which shows that the depressed quartic of (B8) is a biquadratic equation. Using the Ferris’ solution to the depressed quartic equation, we know that the characteristic roots of (B8) is

$$\beta_{1,2,3,4} = \frac{\rho}{2} \pm \sqrt{\left(\frac{\rho}{2}\right)^2 - \frac{K}{2} \pm \frac{1}{2} \sqrt{K^2 - 4 \det J}} \quad (\text{B9})$$

where  $K = M_2 - \rho^2$ .

From (Dockner and Feichtinger 1991) where they investigate the stability property of a dynamic system with two state variables, we know that the stability nearby the neighborhood of a stationary point arises when

$$K < 0, \quad 0 < \det J \leq \left(\frac{K}{2}\right)^2 \quad (\text{B10})$$

for the asymptotical stability with real roots, or

$$\det J > \left(\frac{K}{2}\right)^2, \quad \det J - \left(\frac{K}{2}\right)^2 - r^2 \frac{K}{2} \begin{cases} < 0 \\ = 0 \end{cases} \quad (\text{B11})$$

for the stability of periodic motions or limit cycles with the complex roots, respectively.